PEDIATRIC KNOWLEDGE BRIEF – 2013

EasyRECD™

An easier way to incorporate individual ear canal acoustics into the pediatric fitting process

EDITORS OF ISSUE

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ABSTRACT

Real Ear to Coupler Difference (RECD) measurements are an important part of the pediatric fitting process. RECD measurements ensure the individual ear canal acoustics are incorporated into the gain prescription, resulting in a more accurate fitting. Relying on average RECD values has significant problems, as the ear canal volume from one child to the next varies significantly (Bagatto, 2001). This can result in a hearing aid that can be either too loud or too soft for the child. Despite the benefits of measuring and applying individualized RECDs, the measurement is often omitted. The main reasons being a lack of equipment, or the procedure is viewed as being too time consuming and overly complex (Moodie et al., 2011).

The barriers associated with conducting this important procedure must be overcome to obtain optimal gain prescription for more children with hearing loss. For this reason, Oticon developed a hearing aid-measured procedure to incorporate individual ear canal acoustics into the fitting. This procedure was developed in close collaboration with leading experts in the field of pediatric audiology, from Western University, London, Ontario. The tool, EasyRECD™, makes it easy for clinicians to incorporate individual ear canal acoustics into the fitting. The RECD measurement is done with the hearing aid itself, without the need for any real-ear external measurement equipment. When developing this tool, the goals were to create a feature that was accurate, time-efficient and easy to perform. This article will describe the developmental decision making behind the EasyRECD™ tool and present validity results from the first pilot project of the EasyRECD™ procedure.

Acknowledgement

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For questions regarding the contents of this paper please contact Kamilla Angelo at ang@oticon.dk

Introduction

Pediatric audiologists are extremely busy in their daily working lives. Not only do they have full patient case loads, they are also feeling the pressure of tightened public health budgets further stretching their resources (Moodie et al., 2011). Despite these pressures, the demands on the pediatric audiologist in providing accurate amplification are particularly high (McCreery et al., 2013). Guidelines and protocols have been developed to assist the audiologist in fitting children with hearing aids to give them the audibility that they so urgently need (American Academy of Audiology, 2013). The reality is, that living up to best practice is not always achievable for pediatric audiologists because of time limitations or lack of the required equipment (Bamford et al., 2001, Moodie et al., 2011).

For many years, researchers have strongly advocated that individual RECD measurements should be an integral part of the pediatric fitting process (Erber, 1973, Moodie et al., 1994, Seewald et al., 1999, Munro and Hatton, 2000). Measuring RECDs is now part of recommended fitting protocols and best practice guidelines (AAA, 2013). However, obtaining an RECD can still be a challenging task. Knowledge of the individual ear canal acoustics, and predicted real ear performance is incredibly useful. The RECD measurement not only can be used to correct the audiogram, but is also used to predict the amplified sound pressure level in the real ear. Within the past few years, several attempts have been made by manufacturers at designing hearing aid-measured RECD systems (Yanz and Galster, 2008, Widex, 2010) or feedback-based estimations of RECDs (Phonak, 2010). Research has shown that these in-situ RECD technologies have been met with challenges in terms of clinical adoption (Digiovanni and Pratt, 2010, Kuk, 2011, Scollie et al., 2011). The obvious advantage of hearing-aid-measured RECD, is that in-situ measures correct the gain prescription using the identical transducer and coupling to the ear that is used after the fitting (i.e. the hearing aid including hook, filter, tubing and earmold). However, prior to adopting alternative RECD measurement procedures in the clinic, the following important questions must be asked: What is the clinical validity? Will the alternative procedure result in the desired real ear performance?

EasyRECD™ validity

Clinical pilot testing of the EasyRECD™ procedure was conducted together with colleagues at Western University, Ontario Canada.

Procedure:

The child's EasyRECD™ was measured using the recommended protocol from Oticon, Inc. The individually measured EasyRECD™ was then used to program the child's hearing aid based on the child's audiometric threshold values and the Desired Sensation Level (DSL) method version 5.0a that is embedded within the Genie software. The programmed Sensei hearing aid was attached to a BTE coupler and positioned in the Audioscan Verifit test box. Predicted real-ear measurements were obtained for a 65 dB SPL speech input as well as an MPO measurement (90 dB SPL) of hearing aid performance.

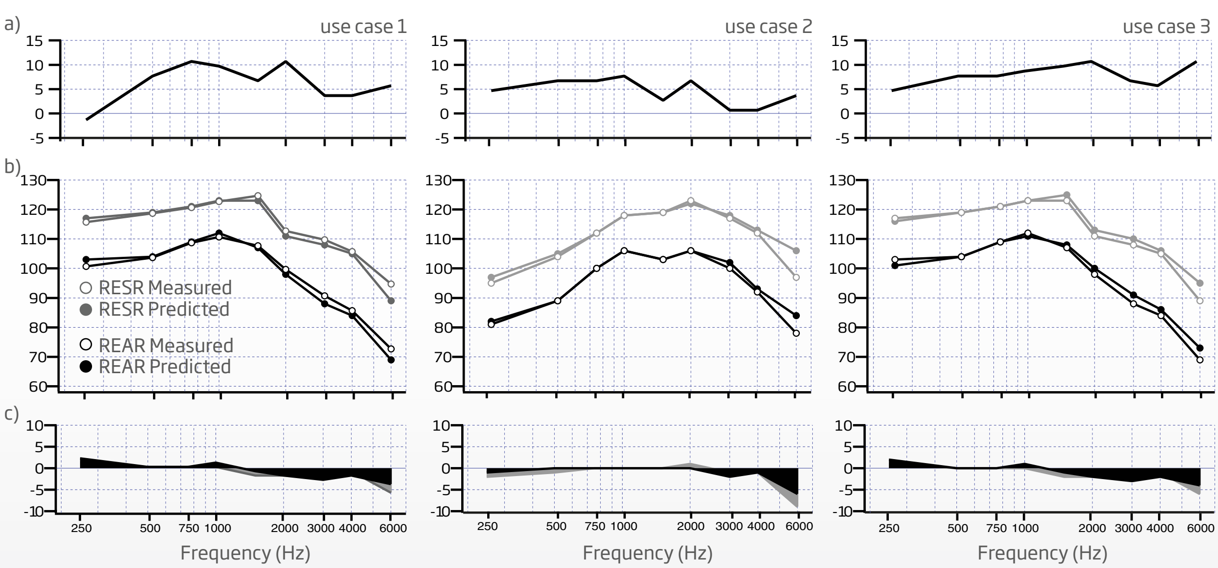


Figure 1: Clinical use cases of EasyRECD™. *The three columns represent use cases from children at the age of 8, 10 and 7 (left to right). The Sensei device was programmed according to the audiogram of the child adjusting the prescription with the individual EasyRECD™ values* ***(panel a)****. 2cc coupler measurements in the Verifit using the EasyRECD™ values were subsequently applied in order to predict the SPL in the child's ear (REARpredicted, 65 dB SPL and RESRpredicted, MPO 90 dB SPL, solid markers,* ***panel b****). To evaluate the accuracy of this prediction real ear aided (REARmeasured) and saturation responses (RESRmeasured) were also obtained directly on the child's ear with a standard probe tube real ear measurement (open markers,* ***panel b****). The differences between the predicted and measured responses of the REAR (black) and the RESR (grey) are shown in* ***panel c****.*

All measurements were conducted on the Verifit using their Speechmap/DSL implementation. For comparison purposes, a real-ear measurement of hearing aid performance was obtained with the probe-tube placed near the eardrum of each child and using the Verifit with signal levels of 65 dB speech and MPO. To avoid any microphone location and head diffraction effects affecting the real ear measurement the test signal was delivered directly to the hearing aid using an Amigo R12 FM receiver and Amigo T30 transmitter. The microphone connected to the T30 was simply placed in the Verifit test chamber during the measurement.

Results:
Figure 1 provides results from three separate children of the pilot validity study. The EasyRECD™ measurements of each child is presented in figure 1a, illustrating the individual differences between the children. In each case, predicted real-ear performance utilizing the individual EasyRECD™ measurement closely approximated the real-ear measurements for each child (Fig. 1b). At most audiometric frequencies from 250 to 4000 Hz, the difference for the real-ear aided response measures (real-ear minus predicted real-ear, Fig. 1c) in all three case examples was less than 2 dB. At 6000 Hz the average difference of the three examples was slightly higher. Similarly, the difference between the measured and predicted real-ear saturation response (RESR) measures as less than 2 dB, except at 6000 Hz where the average difference was 6 dB. This larger difference seen at 6000 Hz is consistent with other studies (Moodie et al., 1994). The final pilot validity study (n=8) has been completed and results indicate that when pooled across all frequencies, there was no significant difference between predicted versus measured real-ear measurements for REAR and RESR.

Prior to the clinical study at Western University, the EasyRECD™ system was technically verified at Oticon. During the testing, an artificial 0.34cc ear canal was used rather than a real ear canal to completely eliminate the practical errors associated with real ear measurements such as the probe tube placement (Tharpe et al., 2001, Bagatto et al., 2006) or earmold leakage (Hoover et al., 2000, Bech, 2007). The artificial ear canal is a cylindrical cavity (L: 12 mm, D: 6 mm) similar to the HA-2 2cc coupler, only smaller in size to resemble the pediatric ear canal. The precision of an RECD measurement is influenced by the relative magnitude of the output impedance, i.e. transducer/hearing aid together with its coupling to the ear (tubing length and diameter) and the physiological acoustic impedance presented by the ear canal with the tympanic membrane. The degree to which the RECD measurement truly represents the physical volume of an ear canal is greatest if the impedance of the sound source greatly exceeds that of the ear (Munro and Salisbury, 2002). It is therefore important to show the validity of an RECD procedure within an acoustic cavity which is as small as an infant's ear. For comparison, a similar measurement was performed with the 0.34 coupler in the Verifit system. The difference between the two systems proved to be less than 1.2 dB at any frequency with an average deviation of 0.5 ± 0.3 dB across all audiometric frequencies. This confirms excellent performance of the EasyRECD™ system even within a small acoustic space which presents a higher impedance load on the sound source than when using the 2cc coupler or an adult ear (Fig. 2). The test-retest reliability of the EasyRECD™ equipment was ± 0.25 dB (error bars in Fig. 2) as measured in the artificial 0.34cc ear canal reassembling the tools between every recording.

EasyRECD™ design

A hearing aid-based RECD system must be fast, yet highly reproducible and insensitive to interference by noise. This places significant demands on the mechanical components of the RECD equipment. The probe tube carries the sound present at the tympanic membrane during the RECD measurement, and delivers this sound to the microphone in the EasyRECD™ adapter/programming module. For optimal delivery of the signal to the RECD microphone across all levels and frequencies, the connection between the probe tube and the hearing aid must be hermetically sealed. Oticon does not use the hearing aid microphones for this measurement, since the probe tube attachment to the microphones on BTE

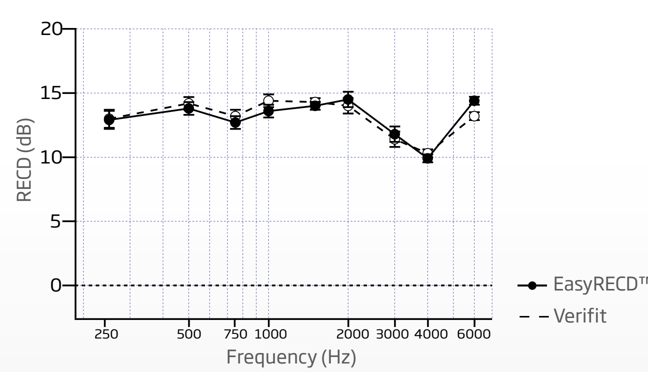


Figure 2: Acoustic precision of the EasyRECD™ equipment. *RECD data was obtained using a custom made artificial child ear canal with a 0.34 cm^3 volume. The RECD measurements were done using the EasyRECD™ equipment and the Verifit procedure, respectively. The mean difference between methods was 0.5 ± 0.3 dB across frequencies, ranging from -0.5 to 1.2 dB. The tools were re-assembled and re-calibrated for every trial and the test-retest repeatability was 0.08 – 0.25 dB and 0.3 – 0.7 dB (S.D. error bars on curves, n = 10) for the EasyRECD™ system and the Verifit, respectively.*

instruments has previously been an issue in other integrated RECD systems (Yanz and Galster, 2008, Widex, 2010). Rather, the microphone used for the EasyRECD™ measurements is integrated into the Oticon EasyRECD™ programming module. The EasyRECD™ module interfaces to the bottom of the BTE and RITE instruments, and has the same functionality as the programming module used by the rest of the Oticon products. The probe tube connects to the shoe via a magnetic connection which ensures a consistent acoustic coupling to the RECD shoe. If a strand of hair should accidentally be caught between the magnetic connectors, the rubber coating at the end of the probe tube will absorbs this, retaining a tight seal. Using a magnet, it is highly unlikely the probe tube could be positioned incorrectly relative to the programming module.

It is almost impossible to manufacture hearing aids, hooks, dampers, microphones or probe tubes which are 100% identical. Therefore, a calibration step must be performed to remove production tolerances and increase the reliability of the RECD measurement. The small red calibration adaptor (Fig. 3c) is used for calibrating the RECD system. The hook of the hearing aid connects to one end, and the probe tube into the other end (Fig 3, mid). The acoustic loss in the calibration is less than 0.3 dB and the positioning of the probe tube in the long end of the calibration adaptor is highly intuitive and reproducible.

The hearing aid microphones are disabled during the EasyRECD™ procedure. Therefore, there is no need to cover the hearing aid microphones, as has been the solution with other in-situ RECD systems where the microphones needed shielding to prevent interference of amplified sounds or feedback. However, it is necessary to perform the measurement under relatively quiet conditions as direct sound from the child and room will affect the recording. The system monitors the background noise and will not allow the measurement to run if the noise level is too high. This is indicated by the noise level meter in the EasyRECD™ tool (Fig. 4).

The actual EasyRECD™ measurement is performed by the hearing aid itself, by estimating the impulse response between the signal send out of the speaker and the signal received through the EasyRECD™ microphone. The signal used is a stepped pure tone sweep from 233 to 6500 Hz in 34 steps and takes less than 5 seconds. By using the impulse response with pure tones the system is fast and very robust towards external noise (Fig. 4). The speed of the recording increases the likelihood a valid measurement will be obtained, even when a child is active and/or noncompliant. Also, if additional measure-

Figure 3: EasyRECD™ tools. *EasyRECD™ includes three tools as well as the RECD programming module. The system assembles for calibration as depicted in the illustration (middle).* ***a)*** *A clinically familiar RECD programming shoe interfaces to the bottom of the BTE hearing aid and has the same functionality as the classic Oticon programming shoe. It holds a built-in microphone and magnet for probe tube attachment.* ***b)*** *The EasyRECD™ probe tube has a magnet in one end for attaching it on to the programming shoe. The magnet is covered with silicon which has the effect of creating a perfect seal if a hair should accidentally get caught in the coupling between the probe tube and the RECD shoe.* ***c)*** *The red calibration adaptor is used to assemble the hearing aid and probe tube for calibration. The same adaptor can be used for both BTE and RITE styles.* ***d)*** *The ear strap attaches to the probe tube marking the desired insertion depth in the child's ear canal. The ear strap holds the probe tube in place in the ear of the child. The EasyRECD™ system is not dependent on the ear strap, but the audiologist can use it if he/she finds it helpful. When pulling on the small pin-like structure (bottom, right) the probe tube can be removed without removal of the earmold.*

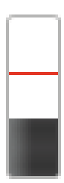
ments are necessary (because of noise or adjustment of the ear mould position), the time required to repeat the measurement is negligible. Overall, the EasyRECD™ procedure from calibration to finalization (Fig. 5) can be completed within approximately 3 minutes, even by the novice clinician.

Troubleshooting

The volume of the ear canal is the main physiological factor which affects the RECD values across frequencies. Ideally, what we obtain from a real-ear measurement accurately reflects the acoustic response of the ear, *only*. Unfortunately, the RECD is also highly sensitive to the choice of methodological approach such as coupling to the ear, tubing length/diameter and transducer type (Munro and Salisbury, 2002, Gustafson et al., 2013). Because of the inherent variability in the measurement, it can be difficult to identify measurement errors.

RECD measurements are in general more reliable and reproducible in the mid-frequencies. At very high or very low frequencies, greater variation and less consistency of the measurement is seen (Tharpe et al., 2001). Very negative or very positive RECD values in the high frequencies may be attributed to insufficient probe insertion depth and measurement at minimum of the standing wave in the ear canal (Storey and Dillon, 2001, Saunders and Morgan, 2003). A tight-fitting closed earmold results in positive RECD values across all frequencies (Hoover et al., 2000). Thus, very negative RECD values in the low frequencies may be attributed to a poor seal between the ear canal and transducer. If acoustic leakage is the actual problem, it is suggested that the measurement is repeated after better placement of the earmold or with lubrication which will improve the seal between the mold and ear.

Sound leakage from the ear canal cannot be avoided if the child uses a vented earmold or is fitted with an open RITE or Corda (thin tube) system. In these cases, it is recommended that the vent is plugged or that a closed power dome is used when running the EasyRECD™.



Noise Level

Figure 4: Noise level meter in Genie. *A probe tube registers all sound, including background noise. When the probe tube is placed in the ear, the noise level can be affected by the child speaking, crying, or moving head or jaw. When the instruments and the probe tube are placed on the table, the noise level can be affected, e.g. by a laptop fan. To keep the audiologist informed about the noise level, a noise level meter is placed between the left and right ear graphs in the Calibrate and Measure steps in the EasyRECD™ tab. The red line in the meter marks the noise level limit for reliable measurement. If the noise level exceeds the limit for reliable measurement, the indicator bar turns red, and it will not be possible to start any calibration or measurement.*

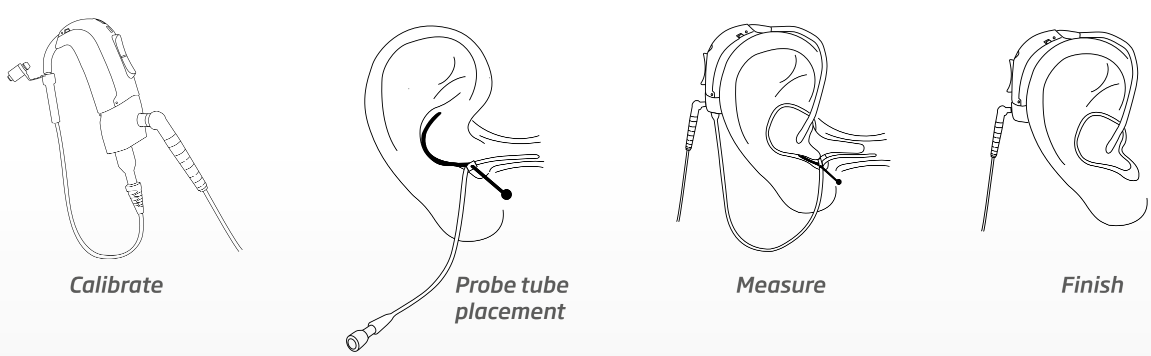


Figure 5: EasyRECD™ measurement flow. *EasyRECD™ completes in four steps. The EasyRECD™ tab in the Oticon software, Genie, runs through the process step-by-step.* ***Calibrate:*** *The probe tube and calibration adaptor are attached to the hearing instrument with the RECD programming module as illustrated.* ***Probe tube placement:*** *Having marked the probe tube insertion depth with the easy grip strap, the probe tube is placed in the ear canal of the child. The easy grip strap holds the probe tube in place, leaving the hands of the audiologist free to do other tasks.* ***Measure:*** *Place the earmold with the hearing aid on the child's ear, attach the magnet of the probe tube to the programming module on the hearing aid and press "measure" to acquire the RECD data.* ***Finish:*** *The probe tube can now be pulled out using the easy grip strap (pin-like structure in Fig. 3 d). When the EasyRECD™ measurement is used in programming of the hearing aid, the RECD values are applied to adjust for the individual ear acoustic both in the calculation of the SPL thresholds and in the output gain prescription. This approach mimics the handling of RECDs by the Desired Sensation Level.*

Plugging the ear canal gives the most precise RECD measurement of the ear canal response at frequencies below 700 Hz. However, the EasyRECD™ system does handle open or vented measurements. The acoustic impedance of a vent is greatest in the high frequencies, thus inconsistencies with real ear probe tube measurements are mainly a concern at low frequencies. When using a vented earmold, the EasyRECD™ system estimates at what frequency this vent effect is expected to cross 0 dB. Between this point and down to the value of the predicted age-average RECD value at 250 Hz, the EasyRECD™ values will be interpolated logarithmically. This ensures the uncertain negative data points that are jeopardised by the vent effect in the low frequencies, will be excluded in the final EasyRECD™. In this way, the measurement uncertainty from the vent is eliminated in the low frequencies and at the same time the valuable individually measured mid-high frequency data is still used to ensure a fitting that will be more precise than using the predicted normative RECD data (Bagatto et al., 2002). This strategy needs further clinical investigation to measure its validity.

Conclusion

The differences in sound pressure levels that are uncovered when measuring individual ear canal acoustics of children with personalized hearing solutions are relatively small, but certainly not trivial (Erber, 1973). The whole premise of fitting hearing instruments to children relies on confirming the individual amplification requirements of the child are achieved. For the hearing instrument to optimally match the limited capacity of the impaired ear, sound must often be compressed to within a frame of 10–40 dB dependent on the degree of hearing loss. Thus, neglecting 5–10 dB of amplification can be critical in a pediatric fitting. Completing the EasyRECD™ measurement and incorporating this procedure into daily practice provides verification information of individual ear acoustics that increase the accuracy of the fitting compared to the alternative of *not* verifying the fitting with the individual ear acoustics. It should thus not be regarded as replacement of adhering to the best practice standards using diagnostic equipment for verification purposes. However, by providing a tool that is accurate, easy, and time efficient, it is our hope that the EasyRECD™ procedure will increase the probability that pediatric clinicians include individual ear acoustics when fitting hearing impaired children with amplification.

Challenge:	Cause:
Negative values overall	Negative values means that the ear canal of the child is larger than the 2 cc coupler. For the majority of cases this is unrealistic.
Negative values in the low frequencies only	Potential sound leakage. Ensure correct earmold placement and try lubricating the earmold to obtain a better seal. If the problem persists consider getting a new earmold.
Low values in the mid- to high frequency range	This is normal if the earmold tubing is long. Alternatively the probe tube is squeezed. Try re-inserting the probe tube and earmold.
High frequency roll off	The probe-tube is not close enough to the tympanic membrane. Try re-inserting the probe to approx. 5 mm from the ear drum using an otoscope.

Table 1: *Obtaining a high quality RECD measurement requires practice and should include a critical assessment of its validity (Bagatto, 2001). An RECD measurement often deviates due to known practical causes. The above table lists the most general errors typical to RECD probe tube measurements. Other patient-related problems such as middle ear effusion, and ear drum perforation can also shape the RECD values in both level and frequencies. The RECDs can vary substantially between children at the same age because their ears grow at different rates. Therefore the predicted age-related RECD's are only an approximation to reality. In the EasyRECD™ tool, the predicted RECD for the relevant age of the child is shown. A pop-up message: "The curve is outside expected range", prompts the audiologist if the measured EasyRECD™ deviates from the predicted age-average RECD by more than ± 10 dB. It is thought of as a help for the audiologist and for this reason, a trouble-shooting guide is provided with the Genie software with guidance on how to handle measurement points falling outside the typical range.*

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People First

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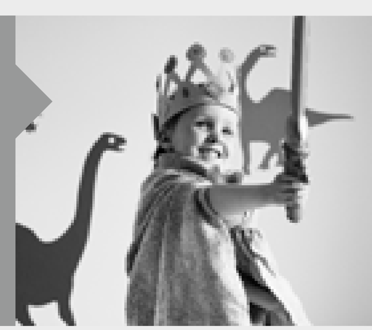
child friendly hearing care

Our pediatric audiological mission is to ensure a better future for every child with hearing loss. We will deliver solutions, tools and techniques that optimize auditory and cognitive habilitation, embrace the complexities of growing up with hearing loss and empower you to adapt solutions to each child's developmental stage on their journey to adulthood.



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