THE EFFECT OF TYMPANIC MEMBRANE PERFORATION ON REAL-EAR TO COUPLER DIFFERENCE ACOUSTIC TRANSFORM FUNCTION

Thesis

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Abstract:

Real-Ear-to Coupler Difference (RECD) is the difference in decibels, as a function of frequency, between the SPL at a specified measurement point in the ear canal and the SPL in a 2cc coupler, for a specified input signal.

OBJECTIVE: we investigated the effects of tympanic membrane perforation on the RECD.

METHODS: RECD was obtained using an insertion gain analyzer for 24 adult patients with dry tympanic membrane perforation (group 1) (31 ears) and 20 healthy adult control subjects (group 2) (40 ears).

RESULTS: Cases showed moderate conductive hearing loss. There was no statistically significant difference between both anterior & posterior locations as regards the degree of hearing loss or as regards the RECD. There was a statistically significant difference of RECD at frequencies 250 Hz, 500Hz and 750 Hz, between both groups. The RECD was 3 to 6 dB lower in group 1 than in group 2. There was a statistically significant difference on comparing RECD at frequencies 250 Hz, 500 Hz, 750 Hz and 1000 Hz in right ears, and at frequencies: 250 Hz and 500 Hz and 750 Hz in the left ears of both groups. In group 1, there was no statistically significant difference of RECD values at different frequencies between right and left sided perforations and there was no statistically significant difference of RECD values at different frequencies between both genders except at 1500 Hz. There was no statistically significant correlation between the RECD and the age of the patients or their air-bone gap.

CONCLUSION: RECD in patients with tympanic membrane perforation is lower than normal at frequencies (250 Hz - 750 Hz). We **recommend** that this discrepancy should be compensated for if average normal RECD are used in the pre-selection of target and gain to avoid under-amplification at lower frequencies. However, the large inter-subject variation strongly suggests the need for individual RECD measurements whenever possible in fitting aids for patients having tympanic membrane perforations.

Keywords:

Real-Ear-to Coupler Difference; tympanic membrane perforation.

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ABBREVIATIONS

ABR : Auditory Brainstem Response
AGC : Automatic Gain Control
AI : Articulation Index
ANSI : American National Standard Institute
ASA: American Society of Audiology
BAHA: Bone Anchored Hearing Aid
BTE: Behind the Ear
CHL: Conductive Hearing Loss
CIC: Completely in the Canal
CORFIG: Coupler response of flat insertion gain
cc : cubic centimeter
DSL : Desired Sensation Level
DSL i/o : Desired Sensation Level Input /output
DI : Directivity Index
dB : decibel
EINs : Equivalent Input Noise
HL: Hearing Level.
HFA: High Frequency Average
Hz : Hertz.
ITC: In the canal
ITE : In the Ear
KHz: Kilo Hertz
MLE: Microphone Location Effect
mm: millimeter
NAl-NL1: National Acoustic Laboratories non linear
OSPL 90: Saturation Sound Pressure Level for 90 dB Input Sound Pressure Level
REAG: Real Ear Aided Gain
REAR: Real Ear Aided Response
RECD: Real Ear to Coupler Difference

REDD:	Real Ear to Dial Difference
REIG :	Real Ear Insertion Gain
REM :	Real Ear Measurement
REOG:	Real Ear Occluded Gain
REUG:	Real Ear Unaided Gain
REUR :	Real Ear Unaided Response
RESR:	Real Ear Saturation Response
RTG:	Reference Test Gain
SPL:	Sound Pressure Level
SPLIV:	Sound Pressure Level for a Vertical Inductive Field
T:	Telecoil
TM:	Tympanic Membrane
TMP:	Tympanic Membrane Perforation
UCL:	Uncomfortable level
UWO:	University of Western Ontario
WD:	Working Distance
WDRC:	Wide Dynamic Range Compression

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Introduction

INTRODUCTION

The real-ear-to-coupler difference (RECD) is the difference between the 2cc coupler values and the individual auditory canal values measured with the identical sound pressure and conditions. RECD values are given in dB and for every frequency (**Bohnert and Brantzen, 2004).**

The RECD is a powerful tool that can assist the clinician throughout the various stages of the amplification process (**Pumford and Sinclair, 2001).** RECD is used as an accurate and convenient means of deriving real-ear data. It may be used to estimate accurately the real-ear sound pressure level (SPL) produced by a hearing instrument from measurements using a 2cc coupler (**Moodie et al., 1994; Seewald et al., 1999; Munro and Hatton, 2000**). It may also be used to estimate the real-ear SPL of audiometric data obtained by use of an insert earphone in dB hearing level (HL), if this has been calibrated in a 2cc coupler (**Scollie et al., 1998**). RECD values can also be used to convert real –ear targets to 2cc coupler targets to assist with selection of hearing instruments via manufacturers' specification sheets (**Pumford and Sinclair, 2001).**

Given the difference in volume and impedance between the ear and the coupler, RECD values are generally greater than or equal to 0 dB (i.e., greater output in ear than coupler for same input signal level). As can be expected, RECD values can vary substantially across age groups (**Feigin et al., 1989**). Individual adult RECDs often confirm closely to the average. However, children—even of similar age—frequently have very different RECD values (**Bagatto et al., 2002).**

The volume of the residual ear canal when aided together with the middle ear input impedance determines the RECD (**Dillon, 2001).** A negative RECD value may indicate an inadequate seal of the transducer to the ear (e.g., foam ear tip), a larger than average ear, a perforated ear drum or a myringotomy tube in place **(Martin et al., 1997).**

Tympanic membrane perforation acting as a vent allows low-frequency acoustic energy to escape into the middle ear cavity. Use of an average RECD transform function to estimate real-ear SPL in subjects with a perforation will overestimate the SPL reaching the tympanic membrane. As a result, the derived real-ear SPL obtained by use of either an insert transducer or a hearing instrument will be overestimated. This has implications for the selection and verification of a hearing instrument **(Martin et al., 2001)**.

AIM OF THE WORK

To investigate the effects of tympanic membrane perforation on the real-ear to coupler difference (RECD for use in pre selection of hearing aid fitting in patients with tympanic membrane perforation.

Electroacoustic Characteristics of Hearing Aids

Electroacoustic analysis of a hearing aid requires 1) a sound source calibrated in amplitude and frequency spectral characteristics to drive the hearing aid. 2) A means of coupling the energy from the hearing aid to the measurement microphone. 3) An electronic processing device for control of the measurement. 4) A method to display the results (**Frye, 2002**).

Two basic forms of electroacoustic analysis systems have been developed. The coupler measurement system uses a sound box to provide the calibrated source as well as a coupler and microphone for collection of data. The real-ear system has the ability of making an electroacoustic analysis of a hearing aid while it is worn by the patient. Many measurement systems can provide both types of analysis **(Frye, 2002).**

Measuring Hearing Aid in Coupler and Ear Simulators

Hearing aids are most conveniently measured in couplers and ear simulators. The standard couplers and simulators allow measurements to be made in different places and at different times under identical conditions **(Dillon, 2001a**).

(a) Couplers and ear simulators:

A coupler is simply a cavity (figure 1). It has a hearing aid connected to one end and a microphone connected to the other. The coupler provides a repeatable way for the hearing aid to be connected to the microphone, and hence to a sound level meter, without sounds leaking out to other places. The standard coupler used for hearing aids has been around for over 50 years and has a volume of 2 cubic centimeters **(Romanow, 1942, quted from Dillon, 2001a).** This volume was chosen because it was an approximation of the volume of the adult ear canal past the ear mold when hearing aid is worn. Unfortunately; it is not a good approximation of the average adult ear canal volume, and its even worse approximation of the acoustic impedance of the ear at high frequencies **(Dillon, 2001a).**

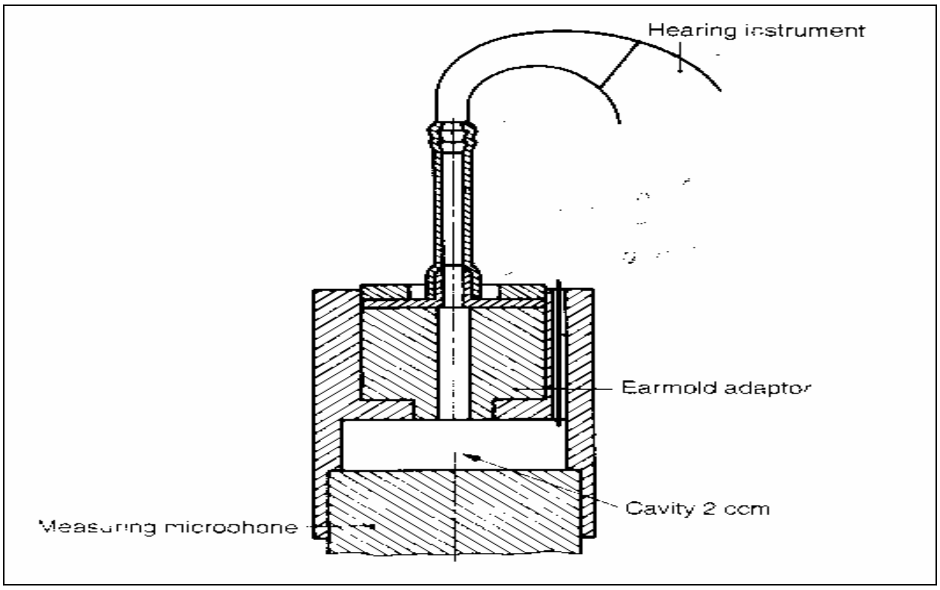

Figure (1): 2- cc coupler for behind the ear hearing instruments (BTE) (Vonlanthen, 2000).

The SPL generated in any cavity by a hearing aid depends directly on the impedance of the cavity, which in turns depends on the volume of the cavity, and on the nature of any thing connected to the cavity. In the average adult ear, the residual ear canal has a physical volume of about 0.5 cc. **(Johonson, 1975).**

This volume acts as an acoustic spring, or more formally, an acoustic compliance. The ear canal, of course, terminates in the ear drum; on the other side of which is the middle ear cavity of about 0.8 cc **(Zwislocki, 1957, quted from Dillon, 2001).).**

The combined 1.3 cc volume determines the impedance for low frequency sounds **(Larson et al., 1993).** As frequency rises, the mass of the ear drum and ossicles cause their impedance to rise, while the impedance of residual ear canal volume falls. Consequently, for increasing frequency, the total impedance doesn't decrease as much as would be expected for a simple cavity. An ear simulator mimics this variation of impedance with frequency. The concept behind ear simulator is that it has the main cavity with a volume from 0.6, and four side cavities, each with volumes from 0.10 to 0.22 cc connected to the main cavity by small tubes, three of which contain dampers **(ANSI, S3.25, 1989 & R- 1995)**.

As frequency rises, the impedance of these tubes rise and they effectively close off, thus causing the effective total volume to gradually fall from 1.3 cc to 0.6 cc. One ear simulator with four cavities is known as the Zwislocki coupler. Another ear simulator in common use is Bruel &Kjaer 4138 ear simulator (figure 2). It operates on the same principles except it has 2 side cavities instead of four. The 2 simulators have a very similar variation of impedance with frequency (**Dillon, 2001a).**