Evaluating Ossicular Discontinuity and Repair Using Wideband Energy Reflectance in Human Cadaver Ears

M. Patrick Feeney1, Iain L. Grant2, David M. Mills1

1Otolaryngology, Head and Neck Surgery, V. M. Bloedel Hearing Research Center, University of Washington, Seattle, WA
2The Ohio State University, Department of Otolaryngology, Head and Neck Surgery.

ABSTRACT

The purpose of this study was to examine the use of wideband energy reflectance (ER) to evaluate an ossicular discontinuity in human cadaver temporal bones. Measurements were obtained on 6 temporal bones at ambient pressures in three conditions: 1) intact ossicular chain; 2) with the ossicular chain cut with an argon laser; and 3) repaired ossicular chain. Laser Doppler vibrometry (LDV) of stapes footplate velocity was used to monitor the effect of the experimental conditions. Disarticulation resulted in a low-frequency drop in ER in a narrow notch below 1000 Hz. The low-frequency notch in ER was eliminated following repair of the ossicular chain with dental cement. LDV measurements confirmed the effect of the disarticulation and repair. A simple series impedance model of the middle ear provided a good description of the response at frequencies below 2000 Hz. It appears that a disarticulation of the ossicular chain produces a low-frequency notch in ER at the zero crossing of reactance that reappears after repair of the disarticulation. These results suggest that ER has potential for use in the diagnosis of ossicular discontinuity and may be useful to monitor the status of a postsurgical ear.

METHOD

Energy reflectance (ER) is the ratio of the sound power reflected from the middle ear to the sound power presented to the ear by a sound source (Keefe et al. 1992; Stinson, 1990; Voss et al., 2008). Unlike traditional admittance measurements, ER is relatively insensitive to probe location in the ear canal, and thus avoids the measurement complication of the combined admittance of the ear canal and middle ear (Stinson, 1990; Voss et al., 2008).

RESULTS

Six sets of measurements were made on each temporal bone with the middle ear open at the mastoidectomy site for all panels, the heavy solid line represents the baseline or normal condition, for both cases the resistance and reactance were similar; the thin solid line is the response measured in the cut condition, and the light solid line is the response after the repair. The same frequency axis applies to all panels, note that it is a logarithmic scale.

Clinical Application

Combined with previous reports suggesting that a distinctive pattern of ER occurs for otosclerosis that is higher than normal in the low frequencies (Allen et al., 2005; Feeney et al., 2003; Shahnaz & Bork, 2006), the current results suggest that ER may be useful as a quick non-invasive test for distinguishing between ossicular discontinuity and otosclerosis. Moreover, the present study also suggests that ER may be useful as a surgical outcome measure to monitor the function of an ossicular repair. Further research is needed to evaluate both pre- and post-operative middle-ear function using ER in ossicular discontinuity and other ossicular disorders such as otosclerosis.

Model Parameters: The reactance of the model seen at the middle ear for the changes observed in the low-frequency range when the stapes connection is severed. Axes are similar to those for panels B and D in Figure 6. The inset indicates the electrical circuit equivalent of the model, which is a series circuit with resistance, R, input reactance, or X, which gives an estimate of the acoustic stiffness, K, in dynamic terms. Panel (C) presents the real part of the model seen at 1000 Hz and 2000 Hz, values in the cut condition are: resistance Rb/Ro ≅ 8x10^{-4}, values in the repaired condition: Rb/Ro = 4x10^{-4}.