

Section 11: Pathogenesis/Diagnosis (Clinical)

Even-order Distortions as Indicators of Endolymphatic Hydrops

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There has been considerable interest in the use of otoacoustic emissions to detect endolymphatic hydrops, even though the results from many studies have not been encouraging. Fetterman¹ concluded that acoustic emissions measurements did not differentiate patients with hydrops from those without, while de Kleine et al.² reported that emissions changes in patients with Meniere's did not differ from non-Meniere's ears with equivalent hearing loss. Recent studies, however, have shown that the even-order emission, f2-f1 is far more sensitive to displacements of the cochlear transducer than is the more commonly used cubic distortion product, 2f1-f2. Sirjani et al.³ showed by calculation and by experiments that even order distortions were highly sensitive to position changes of the cochlear transducer while odd-order distortions were less sensitive to the same manipulations. Both Kirk et al.,⁴ and Sirjani et al.³ showed experimentally that f2-f1 emissions were more sensitive to manipulations of the endolymph than were the 2f1-f2 emissions. Therefore, if acoustic emissions are to be used to detect endolymph volume abnormalities, it seems logical to base such measurements on the f2-f1 emission. The present study has evaluated the feasibility of using f2-f1 emissions as a non-invasive test to document the presence of endolymphatic hydrops.

Methods

A series of cochlear potentials and acoustic emission measurements were made in up to 24 control and 5 hydropic pigmented guinea pigs. Cochlear potentials were obtained from an Ag/AgCl ball electrode placed on the edge of the round window membrane. Endolymphatic hydrops was induced by surgical ablation of the endolymphatic sac an average of 6.5 weeks (SD 1.4) prior to the assessment. The measurement battery included a sound field calibration of all speakers, action potential (AP) thresholds across frequency (10 μ V criterion, 1 kHz to 16 kHz in $\frac{1}{4}$ octave steps), cochlear microphonic (CM) thresholds across frequency (50 μ V criterion, 500 Hz to 8 kHz in $\frac{1}{4}$ octave steps) and acoustic emissions level function (primaries 4000, 4800 Hz at 70 to 90 dB SPL). In addition, low-frequency biased CM and emissions data were collected. The biased data were collected phase-locked to a 4.8 Hz bias tone delivered at levels from 100 dB SPL to 120 dB SPL (these levels are well below those causing dysfunction, due to the low frequency attenuation characteristics of the middle ear). The primaries for biased emissions testing were 4000 and 4800 Hz delivered at equal levels of 80 or 85 dB SPL. Low-frequency biased CM recordings used a 500 Hz probe stimulus delivered at 90 dB SPL. Within the 208 ms period of each cycle of the bias tone, 8 equally-spaced, independent collections of CM or emission data were obtained and analyzed with respect to the bias induced changes of distortion.

Results

AP thresholds were elevated in some, though not all, hydropic animals. Similarly, CM amplitude was reduced in some animals but not in others. Both the 2f1-f2 and f2-f1 acoustic emissions were reduced in amplitude in all hydropic animals.

The changes in f2-f1 emission amplitude during application of low frequency biasing increased as the bias level was increased, in some cases changing the amplitude of the emission peak by over 15 dB between different points on the bias cycle. The biased emissions data were analyzed by comparing them with the calculated, theoretical V-shaped relationship between distortion and displacement.³ The calculated curve was fitted to the experimental data in a least-squares fitting procedure in which only 4 parameters were varied to fit the emissions for the complete range of bias levels. Figure 1 shows examples of a normal and a hydropic animal in which the distortion changes for the complete bias level series were fitted to the V-curve. In normal animals, at each applied bias level, the 8 measured distortion levels during each cycle of the bias closely followed the predicted V-shaped curve. In this example, the correlation coefficient relating the measured to the predicted distortion changes was 0.96. In contrast, f2-f1 emissions in hydropic animals show characteristics that result in a worse fit to the predicted curve. In this example, the f2-f1 emissions increase as bias level is raised, but within each cycle of the bias at a specific level the distortion changes are generally smaller. This results in a poor correlation between the experimental and predicted values, in this case giving a correlation coefficient of 0.27. The correlation coefficients obtained from 12 normal animals and 5 hydropic animals are summarized in Figure 1 (right panel). The mean correlation coefficient for normal animals was 0.79 while the mean coefficient for hydropic animals was -0.01. These groups were statistically significant (t-test, $p=0.001$) even with the inclusion of one control animal (*) that was found to have abnormal tissue in the external ear canal in contact with the tympanic membrane.

A similar analysis of second harmonic distortion in CM recordings with low frequency biasing was also performed (data not shown). The results were totally consistent with the above emissions data, with bias-induced distortion changes closely correlated with the theoretical curves for normal animals (mean correlation coefficient 0.97, $n=24$). The hydropic animals showed lower degrees of correlation with the V-curve (mean coefficient 0.78, $n=5$). This difference was also highly significant statistically (t-test, $p<0.001$).

Discussion

Low frequency biased f2-f1 emissions provide a theoretically-based method that appears capable of detecting endolymphatic hydrops in a non-invasive manner. In the present study, a high correlation of measured distortion changes with the predicted V-shaped curve was only found in normal animals. This method thus shows considerable

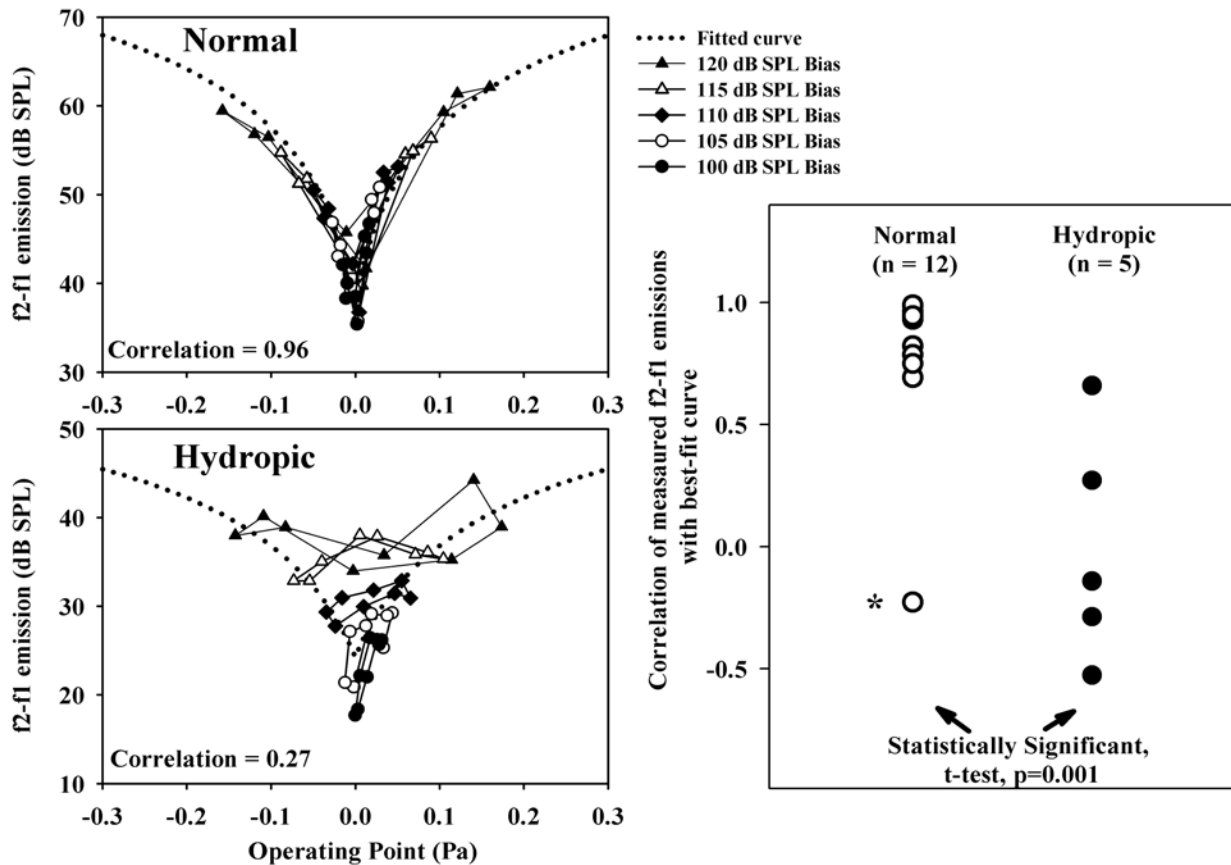


Figure 1 Examples of f2-f1 emission changes in normal (upper left) and hydropic (lower left) animals during presentation of a 4.8 Hz bias tone at the level indicated. Each curve shows the eight distortion measurements during the bias cycle at the indicated level. The operating point scale is calculated as the sum of a baseline operating point value (specific to each animal) and the calculated bias pressure, depending on both the bias phase and bias level for the specific collection window. In normal animals, the emission changes closely fit the predicted V-curve as shown by high correlation values. Hydropic animals differ markedly, with significantly lower correlations with the predicted V-curve (right panel).

potential as a technique that could have value in the diagnosis of human patients.

The primary observations in this study have also been replicated with CM recordings. The CM data are more readily interpreted in terms of the underlying dependence of distortion on the state of the cochlear transducer and on the operating point (the position of the transducer at zero-crossings of the applied stimulus). The CM data show that the baseline operating point in hydropic animals is not systematically displaced on one direction, as might be expected due to the presence of hydrops. Instead, the operating points of hydropic animals were much more variable than in controls and were markedly more sensitive to the low frequency bias stimulus. As the operating point changes were very large in hydropic animals, the measured even order distortions tended to remain at a higher level and did not follow the normal V- shaped relationship.

The specificity of biased even-order distortions for endolymphatic hydrops compared to other pathologies remains to be evaluated. Other pathologies that result in an asymmetric vibration of structures in the ear may also result in low correlation values, as seen in the control animal that had tissue in contact with the tympanic membrane. Nevertheless, a high correlation value from this method

provides a suitable means to exclude the presence of hydrops in the cochlea.

Acknowledgements

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