INTRODUCTION

Background: Otoacoustic emission (OAE) testing is the most common technique used in universal newborn hearing screening. While OAEs do a good job of identifying most children with hearing loss, research has shown that OAEs do not catch all children with milder degrees of hearing loss. Norton et al. (2000) reported a 5.5% false rate for mild hearing loss (thresholds 30-40 dB HL) when using a criterion that resulted in an unacceptably high false-positive rate of 20%.

Recent studies suggest that interaction of two cochlear sources (i.e. nonlinear-distortion and coherent-reflection) may contribute to errors in clinical OAE measurements (e.g., Shera, 2004). If source interaction produces errors, these errors will be most pronounced when recording from normal-hearing and mild-moderately hearing-impaired ears (Maurer et al., 1999). Distortion product otoacoustic emissions (DPOAEs) contain contributions from both cochlear sources (Shera & Guinan, 1999), which manifest as fine structure in the DPOAE response (see Fig. 3). DPOAEs are thought to arise predominantly from the coherent-reflection mechanism (Shera & Guinan, 1999) and, therefore, include contributions from a single cochlear source, the reflection source.

Research Objective: The purpose of this study was to determine the influence of controlling cochlear-source contribution on OAE test performance.

METHODS

Subjects:

Figure 2. Data were collected from 212 normal hearing (NH) and hearing-impaired (HI) subjects with age ranging from 1-10 years. The data included both neonates and adults. All data were collected using a 220-DPOAE (Cant俞eX) and air-conducted otoacoustic emissions (DPOAEs) range from 2f1-f2 to 1 kHz, with a frequency by frequency basis. Subjects were assigned to subgroups based on their DPOAE levels on a screening protocol (x, 55 < 20 dB SPL; y, f < 1.22).

Equipment: Data were collected using custom software (EMAV, Neely & Liu, 1993) that controlled a 24-bit soundcard (CantEx, Digital Audio Labs) housed in a PC. Stimuli and responses were recorded using an ER-10C (Etymotic Research) probe microphone system.

DPOAE Stimulus Conditions: DPOAE fine-structure patterns were recorded by varying f2 in 164-octave steps over 0.1 to 6.3 kHz, with a frequency by frequency basis. Subjects were assigned to subgroups based on their DPOAE levels on a screening protocol (x, 55 < 20 dB SPL; y, f < 1.22).

Controlling for Cochlear Source Contribution: DPOAE fine structure was smoothed using a discrete cosine transform (DCT, Johnson et al., 2007). "Smoothed" DPOAEs contain contributions primarily from the distortion source; the reflection-source contribution has been reduced (Johnson et al., 2006).

AM-SOAE Stimulus Conditions: Reflective OAEs were recorded using an amplitude-modulated (AM) suppressor for measuring the response (Neely et al., 2001). A stimulus with f2=38 kHz, f1=55, and 45 dB SPL, and f2=2, and 4 kHz with the f2/20.88 and 20.85 dB SPL, (Johnson and Mauck, 2010). For all conditions, the suppressor was amplitude modulated at a rate of 8 kHz.

Analyses: Area under the relative operating characteristic (AUC) curve was used to quantify changes in test accuracy when the source contribution was controlled versus the condition where both sources contribute unrestrained. Additionally, false rate (FR), fixed at 5% for NH ears, as a function of behavioral/dose-response category was also evaluated.

RESULTS

Figure 4. Influence of uncontrolled and controlled cochlear-source contributions on OAE test accuracy as quantified by the AUC.

Figure 5. Influence of uncontrolled and controlled cochlear-source contributions on the identification of hearing loss for ears with different degrees of hearing loss.

For majority of the f2 and f2, the test accuracy of the AM-SOE on identifying ears with hearing loss in this group was poorer than the DPOAE accuracy.

For ears in the uncertain-identification group, smoothing resulted in improved identification of hearing loss for several stimulus levels when f2=1 and 2 kHz, but not when f2=4 kHz. In fact, the best performance can be seen when f2 kHz at f2=55 and 45 dB SPL where 100% of the ears with moderate hearing loss were identified (20% increase in FR compared to the DPOAE with uncontrolled source contributions). However, these changes were not statistically significant.

The reflection-source AM-SOAE test performance in this group was never better than the best DPOAE conditions.

CONCLUSIONS

The present data suggest that reducing the reflection-source contribution resulted in improved detection of hearing loss (between 5% and 20% when f2=1 and 2 kHz, but not at 4 kHz, for a clinically feasible false-positive rate of 5%). The small non-significant changes in performance accuracy observed particularly for the uncertain group, where false negative and false positive errors are most likely, suggest that fine structure is not the primary reason these DPOAE responses were ambiguous regarding hearing status.

Additionally, the reflection-source AM-SOAE test performance was never better than the best DPOAE conditions suggesting that our use of the AM-SOAE technique with pre-determined stimulus parameters is not better at distinguishing NH and HI ears compared to any of the DPOAE conditions.

REFERENCES & ACKNOWLEDGEMENTS


