Reverse Propagation of Sounds in the Intact Cochlea

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TO THE EDITOR: In a recent study, Meenderink and van der Heijden (2010) investigated an important mechanism involving the reverse propagation of sounds in the cochlea by measuring group delays of distortion products (DPs). The cochlear microphonic potential (CM) from the round window and the sound pressure in the ear canal were measured when DPs were evoked using a multitone f1 stimulus and a single-tone f2 stimulus (f2 > f1). The reverse delay was obtained by subtracting the middle-ear delay from the delay between the DP CM and the acoustic DP. The authors concluded that they found supporting evidence for the backward traveling wave. This conclusion may be significantly strengthened by addressing the following issues.

Meenderink and van der Heijden (2010) used the round window CM to determine the group delay of the DP at its generation site. However, because of the large distance between outer hair cells and the electrodes, the low spatial resolution of the round window recording is not adequate for accurately measuring the DP phase. The round window potential may also be contaminated or even dominated by the auditory nerve neurophonic potential (Henry 1995). To avoid these uncertainties, DP propagation has been historically studied by intracellular or near-field recording using microelectrodes (Cheatham and Dallos 1997; Gibian and Kim 1982; Nuttall and Dolan 1990), which demonstrated that the DP CM is generated at the DP frequency location. Importantly, it was previously shown that at low and intermediate stimulus levels the group delay of the CM DP is greater than the group delay of the acoustic DP (see Fig. 1 in Brown and Kemp 1985). These data are inconsistent with the recent finding by Meenderink and van der Heijden (2010). The authors used the cross-correlation of the CM and acoustic DP to determine the origins of the DP CM; however, the cross-correlation result carries an ambiguity of about 1/fDPs because the pattern of the cross-correlogram repeats itself with a nearly 1/fDPs time interval.

Although the DP CM was shown to originate from the DP generation sites near the f2, the f1 and f2 CMs were thought to come from the cochlear base and were used to determine the forward and reverse middle-ear delay. Both the f1 and f2 CM have the same uncertainties as the DP CM, which consequently affect the measurement of the intracochlear reverse delay. The forward (166 µs) and reverse (77 µs) middle-ear delay reported by Meenderink and van der Heijden (2010) include not only the middle-ear delay, but also the intracochlear forward delay from the stapes to the f1 or f2 CM generation site and the delay between the microphone and tympanic membrane. This could be a reason why the middle-ear delays reported by the authors are much larger than those in the literature (30–38 µs) (Dong and Olson 2006; Overstreet and Ruggero 2002). The delay from the stapes to the microphone measured by Ren (2006) includes the middle-ear delay and the delay from the ear drum to the microphone, which is not comparable to the middle-ear delay.

When citing the intracochlear pressure data (Dong and Olson 2008), the authors commented that “Exactly these types of phase versus frequency curves formed the basis for the zero delay hypothesis (Ren 2004).” This comment appears to be made under assumptions that there is no difference between pressure and vibration data and that the DP vibration was measured at a cochlear location apical to the DP generation site. On the contrary, Dong and Olson (2008) concluded that their results showed the DP emission is delayed relative to the DP pressure inside the cochlea. Also in contrast, Ren (2004) measured DP vibrations at cochlear locations basal to DP generation sites and showed that the DP arrives at the stapes before it reaches the basilar membrane. Furthermore, Ren found that the DP phase decreases with the distance from the cochlear base, indicating a forward traveling wave. A comprehensive comparison between the DP pressure and vibration measurements was recently published (He et al. 2010).

REFERENCES


