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Analysis by Sweep Frequency Impedance (SFI) Meter of 226-Hz and 1,000-Hz Tympanometries in Neonates

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Abstract

Conventional 226-Hz tympanometry has been acknowledged as a reliable method for detecting middle ear dysfunction in adults and children. However, its application has proved to be inaccurate in neonates younger than 7 months of age. In the present study, therefore, tympanograms of neonates were derived based on sweep frequency impedance (SFI) data and an attempt was made to investigate the reason why conventional tympanometry is inadequate for neonates. Analysis of neonatal tympanograms revealed that the application of a conventional 226-Hz probe tone leads to either a type A or a type M tympanogram. This is possibly due to the intrinsic oscillatory behavior of the external ear canal wall caused by its resonance at around 226 Hz.

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Keywords: Neonates; Middle ear; External ear canal wall; Conventional tympanometry; 226 Hz; High-frequency tympanometry; 1,000 Hz; Sweep frequency impedance (SFI) meter

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1. Introduction

Middle ear dysfunction, such as ossicular chain separation and ossicular chain fixation, leads to conductive hearing loss. Hearing disorders are reported to occur in about 1 to 2 out of every 1,000 neonates[1,2,3,4,5,6] and hearing loss causes a delay in the acquisition of speech and language skills. Early diagnosis and treatment of such disorders in neonates are highly effective for realization of linguistic competence and intellectual development[7]. For this reason, it is recommended that infants are screened for hearing loss before the age of 3 months[8,9,10].

Tympanometry has generally been used to diagnose middle ear dysfunction. Conventional 226-Hz tympanometry has been acknowledged as a reliable method for detecting middle ear dysfunction in adults and children[11,12]. However, the use of conventional 226-Hz tympanometry has proved to be inaccurate in the diagnosis of infants younger than 7 months of age[13,14,15,16]. For instance, neonates who have middle-ear effusion may possibly be regarded as having normal middle ears by conventional tympanometry[15,16,17]. The reason why such tympanograms are obtained has not yet been clarified. Recently developed tympanometry using a 1,000-Hz probe tone has been applied to newborns[18] and has been reported to be more sensitive to secretory otitis media in neonates than the conventional method. Although physical differences in the external and middle ears between newborns and adults/children were suggested as having contributed to such result, no plausible explanation has been forthcoming.

To diagnose middle ear dysfunction, a sweep frequency impedance (SFI) meter was developed in the 1990s[19,20]. It measures the sound pressure level (SPL) in the ear canal and is used to evaluate the mobility of the middle ear. The obtained SFI results are highly effective for diagnosis of middle-ear dysfunction in adults and children[19,20,21,22,23]. In addition, to explain the measurement results in adults, a theoretical model of the external and middle ears in adults was developed. This theoretical model has enabled the estimation of the mechanical properties of the middle ear, which are difficult to measure experimentally.

As above, the SFI meter would have potential as a diagnostic tool for the middle-ear assessment in neonates. Therefore, the SFI meter was redesigned and SFI tests were performed in neonates[24,25,26,27]. As a result, it was found that there were differences in the measurement results between adults and neonates. These differences were reported to be related to the resonance of the neonatal external ear canal wall[24].

Mathematically, it is possible to transform SFI results into tympanograms at any frequencies. In the present study, therefore, tympanograms of neonates were derived from the SFI data obtained in those previous studies to investigate the reason why conventional tympanometry is inadequate to diagnose middle ear disorders in neonates.

2. Materials and methods

2.1. SFI meter

A schema of the SFI meter is shown in Fig. 1. The SFI device consists of a probe containing an earphone and a microphone, an amplifier, a syringe pump, a stepping motor, a pressure sensor, an AD/DA converter and a personal computer. The SFI test is performed as follows. A sound of the sweeping sinusoidal frequency between 100 Hz and 2,000 Hz is presented to the ear canal by the earphone while the static pressure of the ear canal is held constant.

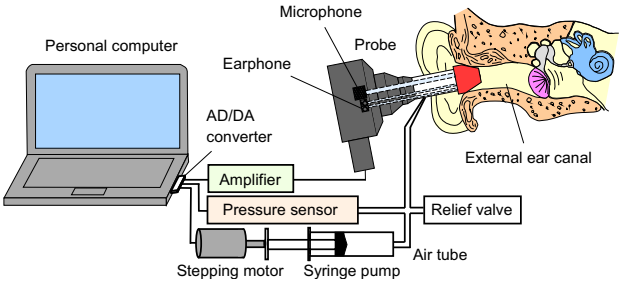

Fig. 1. Sweep frequency impedance (SFI) meter. While the static pressure is applied to the external ear canal by the syringe pump and the sound is delivered to the external ear canal by the earphone, the sound pressure variation of the external ear canal is measured by the microphone.