International Journal of Pediatric Otorhinolaryngology 95 (2017) 51–56

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: http://www.ijporlonline.com/

Acoustic absorbance measurements in neonates exposed to smoking during pregnancy

Beatriz Paloma Corrêa Pucci*, Nayara Michelle Costa de Freitas Roque, Marcella Scigliano Gamero, Alessandra Spada Durante

School of Speech-Language Pathology and Audiology, Santa Casa de Sao Paulo School of Medical Sciences, R. Dr. Cesário Mota Júnior, 61 – 10° andar, Vila Buarque, CEP: 01221-020, São Paulo, SP, Brazil

ARTICLE INFO

Article history:
Received 29 November 2016
Received in revised form
30 January 2017
Accepted 31 January 2017
Available online 4 February 2017

Keywords:
Ear
Middle
Acoustic impedance tests
Infant
Newborn
Tobacco smoke pollution

ABSTRACT

Objective: To analyze acoustic absorbance using wideband tympanometry in neonates exposed to passive smoking during pregnancy.
Method: A study comprising 54 neonates in the control group (CG – unexposed) and 19 in the study group (SG – exposed) was carried out. Subjects were submitted to the wideband tympanometry test and subsequent analysis of absorbance of 17 frequencies.
Result: Low frequencies had a lower level of absorbance compared to high frequencies for both ambient and peak pressures, with no difference between the groups.
Conclusion: No effect of passive smoking on acoustic absorbance measurements in neonates was observed.

1. Introduction

Recent studies have shown that exposure to cigarette smoke during pregnancy can constitute a risk factor for hearing of the neonate, and may also lead to serious complications such as low birth weight, prematurity, placenta problems and risk of bleeding [1–5].

Neonates exposed to passive smoking have reduced cochlear physiology, evidenced by lower response levels of otoacoustic emissions (OAE), prompting the present study to ascertain whether middle-ear measurements are similarly affected. Acoustic absorbance measurement is a procedure for detecting minor changes in the middle-ear and consequent otitis media.

Absorbance measurements are performed using ambient pressure or peak pressure. In the study by Keefe and Simmons [6] (2003) comparing absorbance at peak and ambient pressures in 18 ears of individuals aged over 10 years with conductive hearing loss, absorbance at peak pressure was more accurate for clinical diagnosing conductive loss than ambient pressure, which can be useful for screening.

The prevalence of middle-ear impairments such as secretory otitis media (with effusion) in school children exposed to passive smoking was considered statistically significant in the study of Erdivanli et al. [7] (2012). In a study by Durante et al. [5] 2013, 16 children were excluded from the sample for having been exposed to cigarette smoke at home by parents, and had type B tympanometric curves at a 226 Hz probe tone.

The dearth of studies on passive smoking in the neonatal age group and the principle of new approaches in wideband tympanometry among neonates led to the hypotheses of the present study that neonate exposed to passive smoking during pregnancy have typical absorbance outcomes at peak and ambient pressures compared to the control group, for having been subject to the effects of cigarette substances on the ear canal and, more specifically, in the middle ear.

The objective of this study was to analyze acoustic absorbance using tympanometry by wideband stimuli in neonates exposed to tobacco smoke during pregnancy, according to group (study and control), frequencies (226–8000 Hz), pressure (ambient or peak) and ear (left and right).

* Corresponding author.
E-mail address: beatrizpcpucci@gmail.com (B.P.C. Pucci).

http://dx.doi.org/10.1016/j.ijporl.2017.01.036

2. Casuistic and method

This study was approved by the Research Ethics Committee of the Irmandade da Santa Casa de Misericórdia de São Paulo hospital under protocol 771.404. All subjects took part after their legal guardians had received explanation about the study and signed the Free and Informed Consent Form.

2.1. Casuistic

The sample comprised 73 neonates recruited from the Pediatric sector of the Irmandade de Misericórdia da Santa Casa de São Paulo hospital. The participants were hospitalized in the open ward of the Institution and allocated into one of two groups according to the maternal smoking habits in the gestational period.

The Control Group (CG) comprised 54 neonates (32 females and 22 males) unexposed to passive smoking, and the Study Group (SG) comprised 19 neonates (9 females and 10 males) exposed to passive smoking by the mother during pregnancy.

The inclusion criteria for both groups were: term neonate; no indicators of hearing risk [8]; underwent test at 28 days of life or earlier; mother not in use of other drugs, such as cocaine, alcohol or other substances considered toxic; presence of transient evoked otoacoustic emissions (TEOAE) with noise signal ratio $\geq$ 6 dB for at least three frequencies.

The inclusion criterion for the study group was: mother active smoker (maternal smoking during pregnancy).

The exclusion criterion was non-completion of the full study protocol.

2.2. Equipment

A *Titan* (*Interacoustics*) device and the IMP440 C*linical* module was used, with the optional 3D wideband tests and *Wide Band Tympanometry (WBT) research* module. The module automatically extracts the values of the measurements taken and transforms them into spreadsheet data. This spreadsheet is used with Excel, allowing peak and ambient absorbance values for each subject to be analyzed. The frequencies 226 Hz, 257 Hz, 324 Hz, 408 Hz, 500 Hz, 630 Hz, 794 Hz, 1000 Hz, 1260 Hz, 1587 Hz, 2000 Hz, 2520 Hz, 3175 Hz, 4000 Hz, 5040 Hz, 6350 Hz and 8000 Hz were selected, giving a total of 17 frequencies per test ear at ambient pressure, and 17 at peak pressure. The frequencies were chosen based on the literature [9,10].

2.3. Procedures

All tests were performed with the neonate in a natural sleep state while placed within a cot alongside the mother in the rooming-in ward of the hospital during the post-partum hospital stay. After visual inspection of the external auditory canal, the most snug-fitting insert for the neonate's ear size was selected and the probe carefully introduced so as not to wake the baby. The test first was the one most conveniently positioned. Upon placement of the probe into the test ear and confirmation of the side placed (right or left ear), "Start" is clicked and the measurement automatically acquired. The acoustic absorbance measurement took an average of 10 s to perform per ear.

Data extraction was carried out using the "140331 *WBT absorbances and averaged tymp*" spreadsheet. Extraction produces an Excel spreadsheet allowing peak and ambient absorbance values by frequency to be displayed for each subject.

The Wilcoxon, Mann-Whitney, Chi-squared, Fisher and McNemar tests were employed for inferential analysis of results. The level of significance adopted in this study was 5% (p-value $\leq$ 0.005).

3. Results

The number of cigarettes smoked per day by mothers during pregnancy, ranging from 1 to 25, is shown in Fig. 1.

Wideband tympanometric analyses covered a total of 17 frequencies per ear and per pressure, i.e. 17 frequencies for ambient pressure and 17 for peak pressure were tested for the right ear. The same procedure was followed for the left ear.

The absorbance value was a real number between "zero" and "one" and can be converted into a percentage (%), i.e. a displayed value of 0.30, represents 30% absorbed energy (absorbance). "Zero" indicates all energy is reflected, whereas "one" indicates all energy is absorbed.

3.1. Analysis of acoustic absorbance of right ear at ambient pressure by frequency and group

A comparison of the groups for all frequencies is provided in Fig. 2. None of the frequencies showed a statistically significant difference ($p > 0.062$).

Greater absorption in level of responses can be seen for low frequencies for the study group compared to the control group, but the mean absorbance values for both groups are the lowest found among the 17 frequencies assessed. For medium frequencies, the study group had a higher level of absorbance than the control group up to the frequency of 2520 Hz. For acute frequencies, an inversion of values was only observed at 8000 Hz, where the control group had a greater absorbance value than that of the study group. The highest absorption levels can be seen at higher frequencies (6350 Hz and above) compared to the other frequencies assessed.

3.2. Analysis of acoustic absorbance of left ear at ambient pressure by frequency and group

Overall comparison of the 17 frequencies for the left ear at ambient pressure (Fig. 3) revealed no statistically significant difference on intergroup comparison ($p > 0.094$).

A minor difference between the groups was evident for low frequencies. For these frequencies, the absorbance response level of the study group remains similar to that of the control group up to the frequency of 630 Hz. The difference was only 0.01 for two of the frequencies analyzed. Also, for medium frequencies, the level of absorbance in the control group was close to that of the study group. However, levels for most of these frequencies exceeded 0.01 in the study group. For high frequencies, the control group had higher absorbance levels than the study group only for the highest frequency tested of 8000 Hz.

3.3. Analysis of acoustic absorbance of right ear at peak pressure by frequency and group

Comparison of absorbance values at peak pressure between groups for the 17 frequencies are given in Fig. 4. The study group had a higher absorbance value only at the frequency of 5040 Hz ($p = 0.020$). No difference was detected between the groups for the other frequencies ($p > 0.082$).

The response level for high frequencies differed more compared to low and high frequencies, as did the highest level of absorbance.

3.4. Analysis of acoustic absorbance of left ear at peak pressure by group

Comparison of mean acoustic absorbance values of the left ear for the 17 frequencies at peak pressure in the groups studied (Fig. 5) revealed no statistically significant difference for any of the

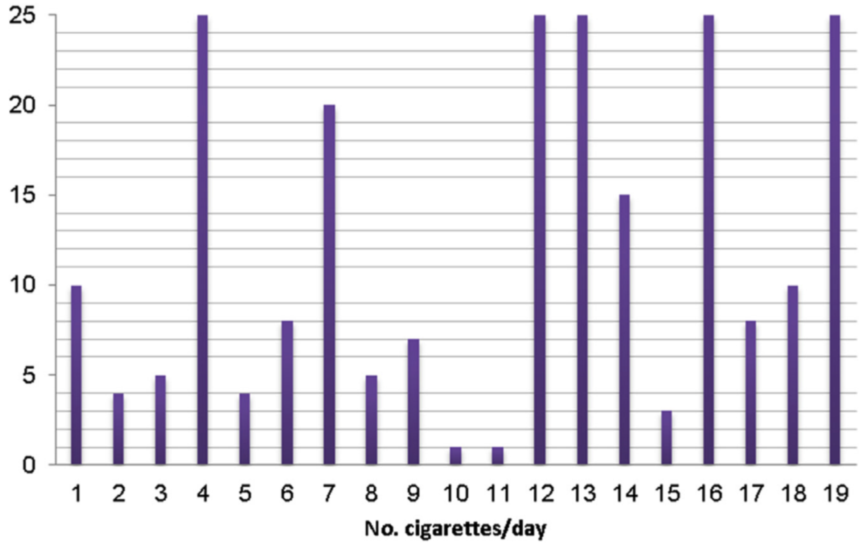

Fig. 1. Distribution of number of cigarettes smoked per day by mothers.

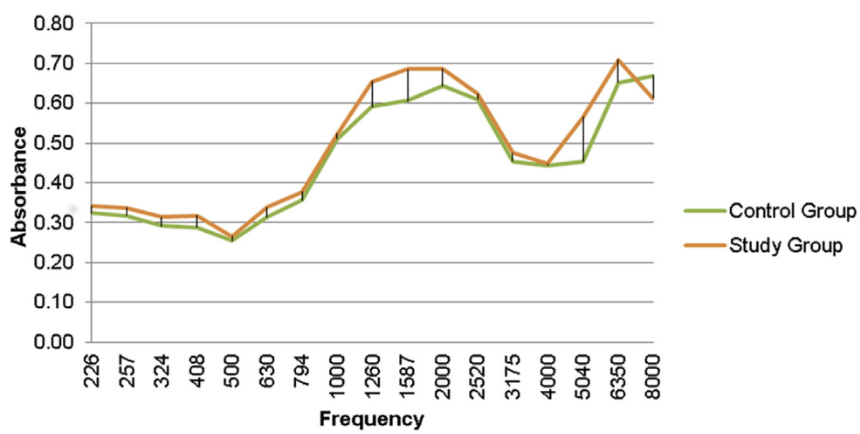

Fig. 2. Comparison of mean acoustic absorbance values of right ear at ambient pressure by frequency and group.

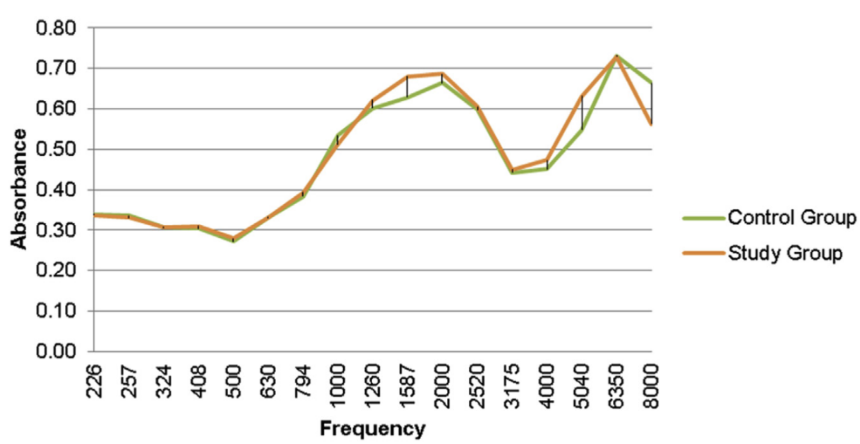

Fig. 3. Comparison of mean acoustic absorbance values at ambient pressure in left ear by frequency and group.

frequencies analyzed ($p > 0.213$).

For low frequencies, the acoustic absorbance level was higher in the neonates exposed to passive smoking at the frequencies 226 and 257 Hz. An inversion of values occurred at the subsequent lower frequencies, where the control group had absorbance values greater than or equal to those of the study group.

For medium frequencies, the study group had greater absorbance values than those of the control group up the frequency of

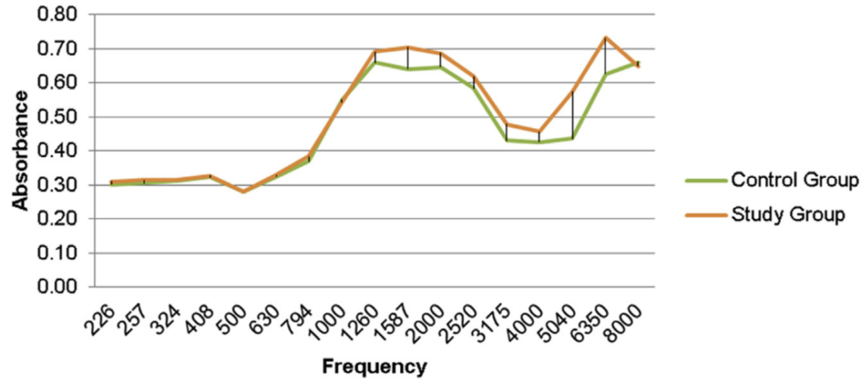

Fig. 4. Comparison of mean acoustic absorbance values at peak pressure of right ear by frequency and group.

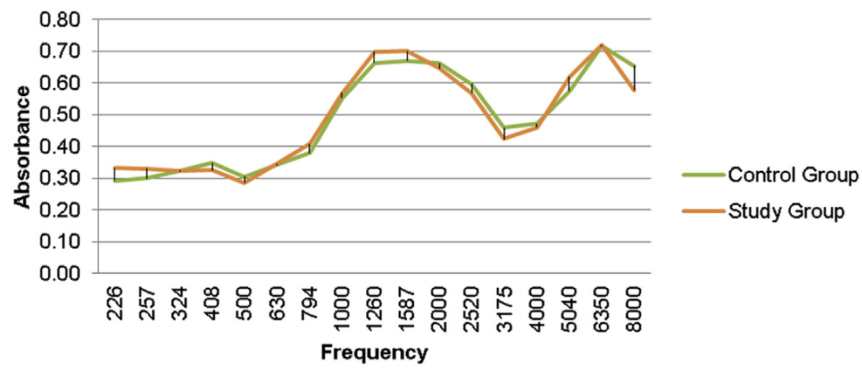

Fig. 5. Comparison of mean acoustic absorbance values at peak pressure of left ear by frequency and group.

1587 Hz. From this frequency up to 4000 Hz, the control group had greater absorption response. The group exposed to smoking during pregnancy had higher levels for the frequencies above this, where the control had higher values than the study group again only at 8000 Hz.

3.5. Analysis of acoustic absorbance at ambient versus peak pressure

On the separate description of the groups by ear and by pressure, comparison of the values found for ambient versus peak pressure for the right ear in the control group revealed a statistically significant difference for the frequencies 324, 408, 500, 630, 1000, 1260 and 1587 Hz ($p < 0.017$), where absorbance at peak pressure had the highest values.

On the same comparison for the left ear in the control group, a statistically significant difference was detected for the frequencies 408, 500,1260 and 1587 Hz ($p < 0.000$), where absorbance at peak pressure had the highest values. Absorbance at ambient pressure had the highest values for the frequencies 226 and 257 Hz ($p < 0.000$).

For the study group, the same comparisons for the right ear showed higher absorbance values at peak pressure for the frequencies 500, 1000 and 1260 Hz ($p < 0.008$). This was also observed for the left ear for the frequencies 1000 and 1260 Hz ($p < 0.005$).

3.6. Analysis of acoustic absorbance of right ear versus left ear

Comparison of right versus left ears for the control group at ambient pressure revealed a statistically significant difference only for the frequencies 5040 and 6350 Hz ($p < 0.032$). At peak pressure, this difference was only observed for the frequencies 4000, 5040 and 6350 Hz ($p < 0.021$). The left ear had higher absorbance values across all frequencies assessed.

The analysis of absorbance by frequency revealed no differences between ears in the study group for ambient pressure ($p > 0.260$) or peak pressure ($p > 0.159$).

4. Discussion

This study investigated the correlation between the effects of passive smoking and acoustic absorbance measurements in neonates.

According to Rosowski et al. [11] (2013), the advent of wideband tympanometry has allowed the execution, with a single probe, of a rapid assessment of a broad spectrum of frequencies. In addition, depending on the device, reflectance (sound reflected by the middle ear) or absorbance (sound absorption) measurements can also be evaluated. Fenney et al. [12] (2013) hold that both these measurements are complementary and can be plotted on graphs as percentages or represented on a scale from 0.0 to 1.0. In the case of this study, the graph (in percentages) can be observed during the execution of the test on the *Titan* test screen. However, following extraction of the values to an Excel file, the values were transformed into a linear scale (from 0.0 to 1.0).

Acoustic absorbance calculations were performed by taking measurements in the external auditory meatus of 73 neonates who met the inclusion criteria applied at data collection. The number of female neonates was greater than males in the control group, although there was no clear reason for this disparity. The gender distribution in the study group was homogeneous. All neonates were assessed in the hospital setting close to their date of discharge. Akin to the study of Aithal et al. [10] (2015), execution time of the tests was less than 10 s per ear.

According to the study by Sanford and Fenney [13] (2008), subject age at time of assessment can influence wideband tympanometric measurements, where the older the subject, the lower the level of reflectance (and greater the absorbance). For the present study, the neonates were assessed close to the date of hospital discharge in order to prevent the presence of vernix and amniotic fluid from affecting absorbance levels [14].

The objective of this study was to identify an effective method for assessing the middle ear in newborns of mothers that smoked or did not smoke during pregnancy, employing the latest procedure of analyzing acoustic absorbance with a multi-frequency probe to compare the two groups. Generally, the literature indicates changes in responses on tone audiometry tests [15–18]; tympanometry with 226 Hz probe tone [5,7], transient otoacoustic emissions [1,4,5,19,20], and distortion product otoacoustic emissions [21] in active or passive smokers. However, this literature review found no studies reporting the presence of changes on acoustic absorbance tests or investigations about wideband tympanometry. Passive smoking is believed to affect only the inner ear, as detected by assessing outer hair cell function using otoacoustic emissions, whereas the middle ear remains unaffected.

4.1. Absorbance values for ambient and peak pressure

After acquisition, absorbance values were determined by extracting data from the Excel spreadsheet supplied by the device manufacturer. This constitutes a module for research in which data were generated from the wideband tympanometry performed. Fifty-four responses of neonates from the control group and 19 from the study group were submitted to the analysis.

All absorbance values for ambient and peak pressure produced the same pattern curve, exhibiting lower absorption at low frequencies and greater absorption at high frequencies. This factor is due to the mass effect and stiffness.

In this study, analyses were conducted at both ambient and peak pressures, although differences between responses had only weak statistical significance. By contrast, the study of Keefe and Simmons [6] (2003) found peak pressure to be more accurate for reaching correct diagnosis than ambient pressure, where the latter can be useful for screening.

The study of Silva et al. [22] (2013) employing reflectance in neonates showed that almost 100% of the energy is reflected for low frequencies; little energy for medium frequencies, whereas high reflection occurs for acute frequencies, reducing again at around 6000 Hz. The data observed in this study are inversely proportional to those found by Silva et al. given that reflectance and absorbance are complementary. Absorbance should be small for low frequencies, rise for medium frequencies, decrease again and increase for acute frequencies. The highest level of energy absorption was found at medium and high frequencies, as reported by the 2009 study of Sanford et al. [23], in which the greatest concentration of energy occurred at frequencies of between 1000 and 8000 Hz.

Regarding reflectance values, the study of Aithal et al. [24] (2013) reported values of 0.45–0.59 for low frequencies; 0.21–0.24 for 1000 Hz–2000 Hz, with values decreasing again to 0.24–0.52 for high frequencies. Absorbance values showed an inverse pattern, i.e. lower for low frequencies and higher for medium and acute frequencies. Aithal et al. [2] (2015) found mean absorbance values of between 0.40 and 0.76. The absorbance values found in the present study, however, ranged from 0.01 for low frequencies to 0.98 for higher frequencies. These values differed to those found in studies by Aithal et al. [24] (2013), Aithal et al. [2] (2015), Sanford and Brockett [25] (2014), in which values between 0.10 and 0.90 were considered normal (i.e., normality of between 10% and 90%). Values outside this area of normality indicate conductive hearing loss, such as secretory otitis media with effusion, history of tympanoplasty, or type C tympanometric curve with a 226 Hz probe tone, as in the case of the study by Stanford and Brockett [25] (2014).

According to Merchant et al. [14] (2010), low values for low frequencies might be explained by sealing of the external auditory meatus with ill-fitting inserts [26,27] or by the presence of vernix or amniotic fluid in the outer or middle-ear of neonates only a few hours old. The authors cited reflectance, although this is also believed to occur for absorbance.

In this study, no significant difference was found between measurements in left and right ears, as also reported by Shahnaz and Bork [9] (2006), Hunter et al. [27] (2008) and Merchant et al. [14] (2010).

5. Final considerations

The objective of the present study was to assess absorbance measurements in neonates exposed and unexposed to passive smoking. To this end, levels for both groups were compared to identify possible differences in middle-ear measurement of subjects. No statistically significant difference was found for the measurements studied.

Further investigations involving acoustic absorbance measurements in individuals of different ages subjected to both passive and active tobacco smoke exposure are warranted.

6. Conclusion

Exposure to passive smoking during pregnancy did not influence acoustic absorbance measurements in the sample of neonates investigated by the present study.

Conflicts of interest

none.

Acknowledgement

This work was supported by the São Paulo Research Foundation - FAPESP [grant numbers 2014/15229-6].

The entire dissertation can be accessed in http://www.fcmsantacasasp.edu.br/images/Pos-graduacao/dissertacoes-e-teses/mestrado-profissional-comunicacao-humana/2016_Beatriz_Paloma_Correa_Pucci.pdf.

References

[1] S. Korres, M. Riga, D. Balatsouras, C. Papadakis, P. Kanellos, E. Ferekidis, Influence of smoking on developing cochlea. Does smoking during pregnancy affect the amplitudes of transient evoked otoacoustic emissions in newborns? Int. J. Pediatr. Otorhinolaryngol. 71 (2007) 781–786.

[2] S.E. Vielwerth, R.B. Jensen, T. Larsen, G. Greisen, The impact of maternal smoking on fetal and infant growth, Early Hum. Dev. 83 (2007) 491–495, http://dx.doi.org/10.1016/j.earlhumdev.2006.09.010.

[3] E. Pretorius, H.M. Oberholzer, W.J. van der Spuy, J.H. Meiring, Smoking and coagulation: the sticky fibrin phenomenon, Ultrastruct. Pathol. 34 (2010) 236–239, http://dx.doi.org/10.3109/01913121003743716.

[4] A.S. Durante, S.M. Ibidi, J.P. Lotufo, R.M. Carvallo, Maternal smoking during pregnancy: impact on otoacoustic emissions in neonates, Int. J. Pediatr. Otorhinolaryngol 75 (2011) 1093–1098, http://dx.doi.org/10.1016/j.ijporl.2011.05.023. Epub 2011 Jun 29.

[5] A.S. Durante, B. Pucci, N. Gudayol, B. Massa, M. Gameiro, C. Lopes, Tobacco smoke exposure during childhood: effect on cochlear physiology, Int. J. Environ. Res. Public Health 10 (2013) 5257–5265.

[6] D.H. Keefe, J.L. Simmons, Energy transmittance predicts conductive hearing loss in older children and adults, J. Acoust. Soc. Am. 114 (2003) 3217–3238.

[7] O.C. Erdivanli, Z.O. Coskun, K.C. Kazikdas, M. Demirci, Prevalence of otitis media with effusion among primary school children in Eastern Black Sea, in Turkey and the effect of smoking in the development of otitis media with effusion, Indian J. Otolaryngol. Head. Neck Surg. 64 (2012) 17–21, http://dx.doi.org/10.1007/s12070-011-0131-z.

[8] Joint Committee on Infant Hearing, Year 2007 position statement: principles and guidelines for early hearing detection and intervention programs, Pediatrics 120 (2007) 898–921. http://pediatrics.aappublications.org/content/pediatrics/120/4/898.full.pdf.

[9] N. Shahnaz, K. Bork, Wideband reflectance norms for Caucasian and Chinese young adults, Ear Hear 27 (2006) 774–788, http://dx.doi.org/10.1097/01.aud.0000240568.00816.4a.

[10] S. Aithal, J. Kei, C. Driscoll, A. Khan, A. Swanston, Wideband absorbance outcomes in newborns: a comparison with high-frequency tympanometry, automated brainstem response, and transient evoked and distortion product otoacoustic emissions, Ear. Hear 36 (2015) e237–e250, http://dx.doi.org/10.1097/AUD.0000000000000175.

[11] J.J. Rosowski, S. Stenfelt, D. Lilly, An overview of wideband immittance measurements techniques and terminology: you say absorbance, I say reflectance, Ear Hear 34 (2013) 9S–16S, http://dx.doi.org/10.1097/AUD.0b013e31829d5a14.

[12] M.P. Feeney, L.L. Hunter, J. Kei, D.J. Lilly, R.H. Margolis, H.H. Nakajima, S.T. Neely, B.A. Prieve, J.J. Rosowski, C.A. Sanford, K.S. Schairer, N. Shahnaz, S. Stenfelt, S.E. Voss, Consensus statement: Eriksholm workshop on wideband absorbance measures of the middle ear, Ear Hear 34 (2013) 78S–79S, http://dx.doi.org/10.1097/AUD.0b013e31829c726b.

[13] C.A. Sanford, M.P. Fenney, Effects of maturation on tympanometric wideband acoustic transfer functions in human infants, J. Acoust. Soc. Am. 124 (4 October 2008), http://dx.doi.org/10.1121/1.2967864.

[14] G.R. Merchant, N.J. Horton, S.E. Voss, Normative reflectance and transmittance measurements on healthy newborn and 1-month-old infants, Ear Hear 31 (2010), 746–654.

[15] K.J. Cruickshanks, R. Klein, B.E. Klein, T.L. Wiley, D.M. Nondahl, T.S. Tweed, Cigarette smoking and hearing loss. The epidemiology of hearing loss study, JAMA 279 (1998) 1715–1719.

[16] C.P. Paschoal, M.F. Azevedo, O cigarro como um fator de risco para alterações auditivas, Braz. J. Otorhinolaryngol. 75 (2009) 893–902, http://dx.doi.org/10.1590/S1808-86942009000600021.

[17] D.C.C.M. Oliveira, M.A.M.T. Lima, Da audiometria tonal limiar em baixa e alta frequência: comparação dos limiares auditivos entre tabagistas e não-tabagistas, Braz. J. Otorhinolaryngol. 75 (2009) 738–744, http://dx.doi.org/10.1590/S1808-86942009000500021.

[18] J. Chang, N. Ryou, H.J. Jun, S.Y. Hwang, J.-J. Song, S.W. Chae, Effect of cigarette smoking and passive smoking on hearing impairment: data from a population–based study, PLoS One 11 (2016) e0146608, http://dx.doi.org/10.1371/journal.pone.0146608.

[19] Vinay, Effect of smoking on transient evoked otoacoustic emissions and contralateral suppression, Auris. Nasus. Larynx 37 (2010) 299–302, http://dx.doi.org/10.1016/j.anl.2009.09.013.

[20] B. Katbamna, N. Klutz, C. Pudrith, J.P. Lavery, C.F. Ide, Prenatal smoke exposure: effects on infant auditory system and placental gene expression, Neurotoxicol. Teratol. 38 (2013) 61–71, http://dx.doi.org/10.1016/j.ntt.2013.04.008.

[21] C. Negley, B. Katbamna, T. Crumpton, G.D. Lawson, Effects of cigarette smoking on distortion product otoacoustic emissions, J. Am. Acad. Audiol. 18 (2007) 665–674.

[22] K.A.L. Silva, J.G. Urosas, S.G.G. Sanches, R.M.M. Carvallo, Reflectância de banda larga em recém-nascidos com presença de emissões otoacústicas evocadas por transiente, CoDAS 25 (2013) 29–33, http://dx.doi.org/10.1590/S2317-17822013000100006.

[23] C.A. Sanford, D.H. Keefe, Y.W. Liu, D. Fitzpatrick, R.W. McCreery, D.E. Lewis, M.P. Gorga, Sound-Conduction effects on DPOAE Screening Outcomes in Newborn Infants: test performance of wideband acoustic transfer functions and 1-KHz tympanometry, Ear Hear 30 (2009) 635–652, http://dx.doi.org/10.1097/AUD.0b013e3181b61cdc.

[24] S. Aithal, J. Kei, C. Driscoll, A. Khan, Normative wideband reflectance measures in healthy neonates, Int. J. Pediatr. Otorhinolaryngol. 77 (2013) 29–35, http://dx.doi.org/10.1016/j.ijporl.2012.09.024.

[25] C.A. Sanford, J.E. Brockett, Characteristics of wideband acoustic immittance in patients with middle-ear dysfunction, J. Am. Acad. Audiol. 25 (2014) 425–440, http://dx.doi.org/10.3766/jaaa.25.5.2.

[26] D.H. Keefe, R.C. Folsom, M.P. Gorga, B.R. Vohr, J.C. Bulen, S.J. Norton, Identification of neonatal hearing impairment: ear-canal measurements of acoustic admittance and reflectance in neonates, Ear Hear 21 (2000) 443–461.

[27] L.L. Hunter, L. Tubaugh, A. Jackson, S. Propes, Wideband Middle Ear power measurement in infants and children, J. Am. Acad. Audiol. 19 (2008) 309–324.