

# Wideband acoustic immittance measures using chirp and pure tone stimuli in infants with middle ear integrity

## Medidas de imitância acústica de banda larga com estímulo *chirp* e tom puro em lactentes com normalidade de orelha média

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### ABSTRACT

**Purpose:** To characterize the wideband reflectance and absorbance values in infants with middle ear integrity. **Methods:** The wideband reflectance and absorbance values for chirp and pure tone stimuli of 31 ears of infants aged 10 days to five months were analyzed. Inclusion criteria considered: 1000 Hz tympanometry, suggesting normal middle ear and the presence of transient evoked otoacoustic emission. **Results:** The reflectance values were shown to be greater for low frequencies, reducing to medium ones and increasing once again to high frequencies, while the absorbance values displayed an opposite behavior. No significant difference was verified between chirp and pure tone stimuli. **Conclusion:** A typical behavior of the measures, characterized by a higher reflectance at low frequencies and higher absorbance at medium frequencies was observed in the population studied.

**Keywords:** Ear, middle; Acoustic impedance tests; Hearing loss, Conductive; Otitis media; Audiology

### RESUMO

**Objetivo:** Caracterizar os valores de reflectância e absorvância de banda larga em lactentes com integridade de orelha média. **Métodos:** Foram analisados os valores de reflectância e absorvância de banda larga, para os estímulos *chirp* e tom puro, de 31 orelhas de 18 lactentes, na faixa etária de 10 dias a cinco meses de idade. Considerou-se como critérios de inclusão: ausência de fator de risco para deficiência auditiva, timpanometria com sonda de 1000 Hz, sugerindo normalidade de orelha média e presença de emissões otoacústicas evocadas por estímulo transiente, na triagem auditiva neonatal. **Resultados:** Os valores de reflectância mostraram-se maiores para as baixas frequências, reduzindo para as médias e aumentando, novamente, para as frequências altas, enquanto para os valores de absorvância, o comportamento foi o oposto. Não existiu diferença significativa entre os estímulos *chirp* e tom puro. **Conclusão:** Observou-se um comportamento típico das medidas estudadas, caracterizado por maior reflectância nas frequências graves e maior absorvância para as frequências médias.

**Descritores:** Orelha média; Testes de impedância acústica; Perda auditiva condutiva; Otite média; Audiolgia

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**Conflict of interests:** No

**Authors' contribution:** PPS collected and tabulated the data, collaborated in the data analysis and preparation of the manuscript and approved its final version for publication; ESA designed the study, collected tabulated and analyzed the data, prepared the manuscript and approved its final version for publication; OACF collaborated in the data analysis, drafted and revised the article, and approved its final version for publication; MTP collaborated in the data analysis, drafted and revised the manuscript and approved its final version for publication; KFA designed the study, oversaw the collection and tabulation of the data, analyzed the data, prepared the manuscript and approved its final version for publication.

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**Received on:** 7/21/2015; **Accepted on:** 10/26/2015

## INTRODUCTION

According to the literature, conductive hearing loss is the most frequent type of hearing loss in children, with a high prevalence in different countries<sup>(1)</sup>. Conductive disorders are known to influence the results of tests routinely performed in clinical practice. For a conclusive diagnosis, therefore, these disorders must be diagnosed with methods that identify with precision middle ear abnormalities in children.

Traditionally, the most used method to evaluate the middle ear is tympanometry using a 226 Hz probe tone following the tympanometric classification proposed by Jerger (1970)<sup>(2)</sup>. However, studies have been unanimous in demonstrating that tympanometry using this probe tone has low sensitivity to identify conductive disorders in neonates and infants up to six months of life<sup>(3)</sup>.

Due to that, studies have analyzed the sensitivity of tympanometry using a 1000 Hz probe tone, showing lower false-negative rates<sup>(4,5)</sup>. Nevertheless, abnormalities may not be identified in some cases that fall into an “undetermined” tympanometric curve<sup>(6-8)</sup>, a circumstance in which the test fails to assist the audiologist in defining the presence or absence of conductive abnormalities.

In this context, the attention has turned back again to the analysis of acoustic reflectance, which has been studied since the decade of 1990's. With technological advances, this test began to be carried out in a more detailed manner and is currently named wideband acoustic immittance. This nomenclature was defined in a consensus among researchers in the field during the Eriksholm Workshop in 2013<sup>(9)</sup>. Among the different measures analyzed with this procedure are wideband reflectance and absorbance.

Wideband power reflectance is the ratio between the reflected and incident energy presented to the external auditory meatus by a probe, therefore representing the amount of energy reflected by the tympanic membrane. Absorbance, in turn, consists in the ratio between the energy absorbed by the middle ear and the incident energy presented to the external auditory meatus. Both measures vary according to the frequency and impedance of the tympanic-ossicular system, and their values are complementary. Reflectance and absorbance consist of a real number between “zero” and “one”, in which “zero” represents all the energy transmitted to the middle ear, and “one” represents all the energy reflected to the acoustic meatus. Both may be represented in percentages<sup>(10)</sup>.

Chirp and pure tone stimuli may be used to analyze these measures, with the first enabling a better frequency resolution and a faster measurement. The use of pure tone, in turn, provides a better signal-to-noise ratio and is a better option in situations of high environmental noise and/or circumstances proper to the condition of the patient<sup>(11)</sup>. It is thus important to compare the clinical results associated with both stimuli. Even though there has been a growing number of studies analyzing these

measures, these studies are mostly international. On a national level, there is only one published study that analyzed wideband power reflectance in neonates with 27 to 78 hours of life<sup>(12)</sup>. Also, previous studies have shown a significant difference when comparing ethnic<sup>(13,14)</sup> and age groups<sup>(15)</sup>.

Thus, the objective of this study was to characterize the results of wideband reflectance and absorbance with chirp and pure tone stimuli in infants with a normal middle ear.

## METHODS

This was an observational, analytical, cross-sectional study developed with approval by the Ethics Committee of the *Faculdade de Odontologia de Bauru, Universidade de São Paulo* (USP), with the number 141.301/2012. We obtained free and informed consent from all parents/guardians of the participants.

The criteria for inclusion in the study were age zero to six months, a transient-evoked otoacoustic emissions test performed with general and frequency band reproducibility values  $\geq 70\%$ , a  $\geq 6$  dB signal-to-noise ratio for each frequency band, and a tympanometric evaluation using a 1000 Hz probe compatible with absence of middle ear abnormality according to the classification proposed by Baldwin (2006)<sup>(7)</sup> adapted from Marchant et al. (1986)<sup>(6)</sup>. We excluded infants with risk indicators for hearing loss<sup>(16)</sup>.

We determined wideband acoustic immittance measurements in the participants using the system Acoustics' Middle-Ear Power Analyzer (MEPA), version 5.0 (Mimosa Acoustics) with chirp and pure tone stimuli. The chirp stimulus was presented with a sound pressure level (SPL) of 60 dB, duration of 1 second, frequencies of 210.9 Hz to 6000 Hz and intervals of 24 Hz with a total of 248 analyzed frequencies. The pure tone stimulus was presented in nine frequencies (250, 500, 750, 1000, 1500, 2000, 3000, 4000 and 6000 Hz) with an SPL of 60 dB and duration of 0.5 seconds.

Wideband acoustic immittance analyzes different measures including reflectance and absorbance, which were determined in the present study. Both were assessed at different frequencies, and the results are presented in percentages. We examined 31 ears in 18 infants aged 10 days to five months during natural sleep. We chose the initial ear based on the child's comfort position. Wideband acoustic immittance measurements were performed on the same day in which the inclusion criteria tests were performed, *i.e.*, tympanometry and transient-evoked otoacoustic emissions.

We used descriptive statistics and paired Student's *t* test to analyze the data, setting the significance level at 5%.

## RESULTS

The comparative analysis of the results obtained with the chirp and pure tone stimuli, performed with paired Student's *t*

test, showed no significant difference between the two stimuli for both measures of reflectance and absorbance ( $p>0.05$ ).

As for the average values obtained with power reflectance, we observed greater reflectance at low frequencies (258 to 750 Hz), showing that the amount of energy absorbed was lower in this range. Reflectance decreased with an increase in frequency (above 750 to 3000 Hz) reaching its lowest value near 1500 Hz. For frequencies above 3000 Hz the reflectance values increased, and when the frequency was close to 6000 Hz the reflected energy values decreased again (Figure 1, Table 1).

With regard to the absorbance values, we observed that they were inversely proportional to the reflectance values, showing lower values at low frequencies (250 to 750 Hz) increasing above 750 Hz reaching peak values close to the frequency of

1500 Hz and then decreasing again above the frequency of 3000 Hz (Figure 2, Table 2).

**DISCUSSION**

A growing number of studies analyzing the efficacy of wideband acoustic immittance measurements in assessing the integrity of the middle ear have demonstrated that this method has high sensitivity and specificity, even in children in the first months of life<sup>(17-20)</sup>. This reflects the importance of characterizing normal patterns in different populations, so the test may be later applied in clinical practice to identify conductive abnormalities<sup>(9)</sup>.

This study characterized the measures of reflectance and

**Table 1.** Mean and standard deviation, in percentage, for pure tone and chirp reflectance by each frequency

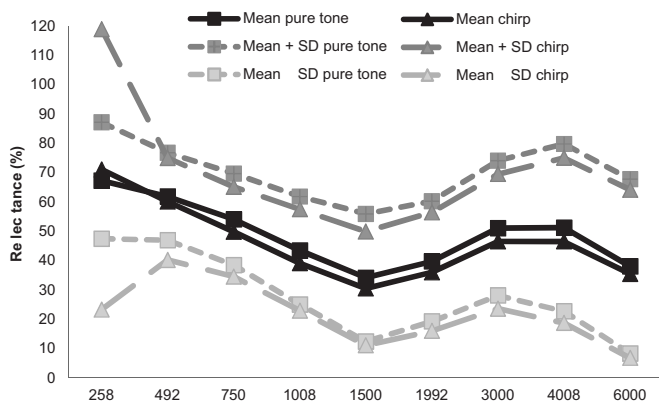
	258 Hz	492 Hz	750 Hz	1008 Hz	1500 Hz	1992 Hz	3000 Hz	4008 Hz	6000 Hz
Mean pure tone (%)	67.31	61.90	54.12	43.48	34.20	39.78	51.12	51.28	38.09
Mean + SD pure tone (%)	87.14	76.80	69.74	61.87	55.96	60.25	74.11	79.79	67.82
Mean - SD pure tone (%)	47.49	47.00	38.51	25.10	12.44	19.31	28.13	22.76	8.36
Mean chirp (%)	71.13	60.16	49.88	39.16	30.54	36.02	46.58	46.54	35.50
Mean + SD chirp (%)	118.91	75.05	65.19	57.55	49.95	56.49	69.53	75.06	64.19
Mean - SD chirp (%)	23.35	40.25	34.57	22.95	11.14	16.07	23.64	18.76	6.82

Note: SD = standard deviation

**Table 2.** Mean and standard deviation, in percentage, for pure tone and chirp absorbance by each frequency

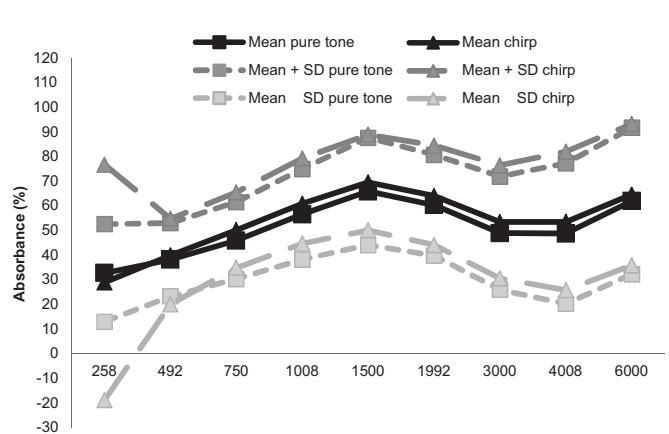
	258 Hz	492 Hz	750 Hz	1008 Hz	1500 Hz	1992 Hz	3000 Hz	4008 Hz	6000 Hz
Mean pure tone (%)	32.69	38.10	45.88	56.52	65.80	60.22	48.88	48.72	61.91
Mean + SD pure tone (%)	52.51	53.00	61.49	74.90	87.56	80.69	71.87	77.24	91.64
Mean - SD pure tone (%)	12.86	23.20	30.26	38.13	44.04	39.75	25.89	20.21	32.18
Mean chirp (%)	28.87	39.84	50.12	60.84	69.46	63.98	53.42	53.46	64.50
Mean + SD chirp (%)	76.65	54.74	65.43	79.22	88.86	84.45	76.36	81.98	93.18
Mean - SD chirp (%)	-18.91	19.94	34.81	44.62	50.05	44.02	30.47	25.68	35.81

Note: SD = standard deviation



Note: SD = standard deviation

**Figure 1.** Mean and standard deviation for pure tone and chirp reflectance by each frequency



Note: SD = standard deviation

**Figure 2.** Mean and standard deviation for pure tone and chirp absorbance by each frequency

absorbance in infants obtained with chirp and pure tone stimuli in the frequencies of 258 to 6000 Hz (Figures 1 and 2), showing higher reflectance at low frequencies and increased absorbance in the range of 750 to 3000 Hz. Similar findings have been observed in a national study<sup>(12)</sup> that has examined wideband acoustic immittance measurements in the first days of life. The study demonstrated that reflectance is greater for frequencies of 258 to 750 Hz and 4000 Hz and lower for those from 1000 to 3000 Hz and 6000 Hz showing greater energy transmission to the middle ear in the latter frequencies.

Similar results have also been shown by international studies<sup>(14,21-24)</sup>, including one<sup>(25)</sup> reporting that the reflectance was greater at low frequencies (250 to 1000 Hz), decreased at medium frequencies (from 1000 Hz to 4000 Hz), and increased again above the frequency of 4000 Hz. Results obtained in a later study<sup>(26)</sup>, in turn, showed that the reflectance decreased along with the frequency when up to approximately 2000 Hz (with the lowest value close to the frequency of 500 Hz) returning to increase above the frequency of 2000 Hz.

The path of the wideband reflectance and absorbance measurements observed in this study may be explained by anatomical and physiological features. Infants have a smaller body structure and, therefore, a reduced middle ear volume, which reflects with a higher resonance frequency than that observed in adults. With greater resonance frequency, greater absorbance and lower reflectance are expected within this frequency range<sup>(25,26)</sup>.

We observed no significant differences in responses obtained with the chirp and pure tone stimuli (Figures 1 and 2). This result is in line with others observed in previous studies evaluating neonates<sup>(12,14)</sup> and children<sup>(27)</sup>, showing that both stimuli were equivalent, and suggesting that they may be used for wideband acoustic immittance measurements.

In contrast, these stimuli are known to probably have distinct clinical applicability since the pure tone stimulus has greater sensitivity when the test is performed in noisy conditions, whereas the chirp stimulus offers better frequency resolution, since it may be performed at intervals of 24 Hz<sup>(11)</sup>. Thus, further studies are still necessary to compare these stimuli in different test circumstances in individuals with middle ear abnormalities. It is also important to assess eventual differences between the stimuli for other wideband acoustic immittance measurements.

Evaluation of the parameters gender and ear (right or left) was not part of the objective of this study since previous publications have not demonstrated a significant difference in results when these parameters were included in the analysis<sup>(14,27)</sup>.

## CONCLUSION

We observed that wideband acoustic immittance values displayed a typical response in infants younger than six months with a normal middle ear, characterized by greater reflectance in the frequency range of 258 to 750 Hz and greater absorbance near the frequency of 1500 Hz.

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