Transient Evoked and Distortion Product Otoacoustic Emissions in a Group of Neonates

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Abstract

Introduction The most commonly used method in neonatal hearing screening programs is transient evoked otoacoustic emissions in the first stage of the process. There are few studies comparing transient evoked otoacoustic emissions with distortion product, but some authors have investigated the issue.

Objective To correlate the results of transient evoked and distortion product otoacoustic emissions in a Brazilian maternity hospital.

Methods This is a cross-sectional, comparative, and prospective study. The study included 579 newborns, ranging from 6 to 54 days of age, born in a low-risk maternity hospital and assessed for hearing loss. All neonates underwent hearing screening by transient evoked and distortion product otoacoustic emissions. The results were analyzed using the Spearman correlation test to relate the two procedures.

Results The pass index on transient evoked otoacoustic emissions was 95% and on distortion product otoacoustic emissions was 91%. The comparison of the two procedures showed that 91% of neonates passed on both procedures, 4.5% passed only on transient evoked otoacoustic emissions, 0.5% passed only on distortion product otoacoustic emissions, and 4% failed on both procedures. The inferential analysis showed a significant strong positive relationship between the two procedures.

Conclusion The failure rate was higher in distortion product otoacoustic emissions when compared with transient evoked; however, there was correlation between the results of the procedures.

Keywords
- audiology
- neonatal screening
- hearing tests

Introduction

Language is a primary function of human development, and a prerequisite for its acquisition and development is the anatomical and physiological integrity of the neurologic and auditory system.[1] Thus, the impact of undetected hearing loss on children's language development and socialization stimulated neonatal hearing screening programs.[2]

Universal newborn hearing screening is a process that aims for early detection of hearing loss and the assessment of hearing in infants with and without risk factors for hearing loss.[3] In 2010 in Brazil, a law was approved that made the performance of evoked otoacoustic emissions compulsory as a method for newborn hearing screening.[4] Evoked otoacoustic emissions is fast, noninvasive, easy to apply, and effective in screening programs.[5,6] Knowledge about the variability of transient evoked otoacoustic emissions (TEOAE) and distortion product otoacoustic emissions (DPOAE) is essential and enhances monitoring the hearing status over time.[7]

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The reviewed literature reports that the most commonly used methods in neonatal hearing screening programs are TEOAE and auditory brainstem response, in a second step of the process, when babies fail TEOAE. The combination of both tests was designed to reduce the number of false-negatives, especially in cases of auditory neuropathy/dyssynchrony, and to improve the sensitivity and specificity of universal newborn hearing screening.[8–21]

TEOAE are a major instrument for detection of hearing impairment of cochlear origin, because they allow the study of the mechanical aspects of cochlear function in a noninvasive and objective manner, independent of nerve action potentials. This method does not quantify hearing impairment, but detects its presence.[9] Thus, the presence of this phenomenon can confirm the integrity of the cochlear mechanism and establishes the functionality of otoacoustic activity of outer hair cells of the cochlea, because TEOAE are present in all individuals whose hearing thresholds are better than 20- or 30-dB hearing level.[10]

There are reports in the literature that TEOAE and DPOAE are equivalent and effective.[22] A study conducted to compare both methods concluded that TEOAE are faster and assess the medium frequency range, and DPOAE are specific to frequency and evaluate the high frequencies.[23]

The most recommended and most used technique in neonatal hearing screening programs is TEOAE; however, because of the frequency specificity of the DPOAE, researchers have investigated them.[24]

When considering the above, the aim of this study is to compare and correlate TEOAE and DPOAE in neonates of a low-risk maternity hospital.

Methods

The design used in this study was a comparative, cross-sectional, and prospective. This study was conducted in a low-risk maternity hospital. This is a subproject of the "Hearing Care Program for Children: Hearing Screening for Children from Zero to Three Years Old" research, funded by Fundação de Amparo à Pesquisa do Estado de São Paulo - FAPESP and approved by the Ethics Committee of the Faculty, protocol 0703/2013.

In this program, newborns discharged from the hospital return in about 1 week for the hearing screening. If the newborn failed the test, the retest was scheduled in about 15 days. If newborns did not attend the test or retest, mothers were contacted to schedule a new date.

Inclusion criteria included signing the Term of Free and Informed Consent and the accomplishment of the two types of otoacoustic emissions: transient and distortion product. Subjects were excluded if they attended the maternity hospital for hearing follow-up due to failure in the test and/or the presence of risk indicators for hearing loss. Thus, 579 neonates who attended the neonatal hearing screening program from May to November of 2013, 279 females and 300 males, were included in the study. The age of the newborns ranged from 6 to 54 days (mean 14).

To achieve the objective, the following procedures were employed: anamnesis, TEOAE, and DPOAE. The audiological anamnesis was based on a questionnaire containing identifying data and questions about pregnancy history, delivery, and the newborn, such as birth weight, gender, age, gestational time (preterm or term), type of delivery (vaginally or cesarean section), complications in pregnancy, Apgar score of the baby at 1 and 5 minutes of life, type of feeding, bottle feeding and/or pacifier use, and risk indicators for hearing loss,[3] plus phototherapy for hyperbilirubinemia.

Evoked otoacoustic emissions were performed with AccuScreen (Madsen - Otometrics, Denmark.), portable equipment used in hearing screening programs. To obtain the responses, the probe was coupled to the external ear of the newborn, preferentially during the neonate's physiological sleep or when he or she was calm and quiet.

We started the screening with DPOAE, followed by TEOAE. TEOAE were evoked by a click stimulus, frequency range from 1.5 to 4.5 kHz, and intensity ranged from 45- to 60-dB hearing level. The minimum stability of the probe was 70%. This equipment analysis shows response peaks; the presence of eight peaks is necessary to consider that the neonate passed the test.

DPOAE were activated by two pure tones, referred to as "primary" tones and abbreviated as f_2 (higher frequency) and f_1 (the lower frequency), that is $f_2 > f_1$. The relation, defined by the ratio expression f_2/f_1, was 1/22.

The intensity levels of stimulus presented was $L_1 = 60$-dB sound pressure level and $L_2 = 50$-dB sound pressure level. The screening used protocol 1 of the equipment that assesses the frequencies of 5, 4, 3, 2 kHz. The test was completed when the neonate presented response in three frequencies (pass) or did not respond at two frequencies (refer).

Statistical analysis used the Microsoft (Redmond, Washington, United States) Excel electronic spreadsheet, Microsoft Office 2010 version, to organize the data and the statistical package SPSS (Statistical Package for Social Sciences - SPSS, USA.), version 21.0. A significance level of 5% (0.05) was adopted. To verify the relationship between variables TEOAE and DPOAE, the Spearman correlation test was used.

Results

The results of TEOAE and DPOAE showed that the pass index of the TEOAE was higher (95.16%) than for DPOAEs (91,54%; ►**Table 1**).

Comparing neonates using the pass/refer index in two procedures unilaterally and bilaterally demonstrated that most of the neonates passed and a minority were referred in both procedures (►**Tables 2** and **3**).

There was a significant strong positive correlation both unilaterally and bilaterally between the TEOAE and DPOAE (►**Table 4**).

Discussion

The knowledge about the variability of TEOAE and DPOAE is essential and enhances the usefulness in monitoring hearing status over time.[7] TEOAE are a major instrument for detection of hearing impairment of cochlear origin, because they allow the study of the mechanical aspects of cochlear function in a

Table 1 TEOAE and DPOAE pass/refer results

Test	Result		Total
	Pass	Refer	
TEOAE	551 (95.16%)	28 (4.84%)	579 (100%)
DPOAE	530 (91.54%)	49 (8.46%)	579 (100%)

Abbreviations: DPOAE, distortion product otoacoustic emission; TEOAE, transient evoked otoacoustic emission.

Table 2 Joint analysis of pass/refer results in TEOAE and DPOAE

TEOAE	DPOAE		Total
	Pass	Refer	
Pass	525 (90.67%)	26 (4.49%)	551 (95.16%)
Refer	5 (0.87%)	23 (3.97%)	28 (4.84%)
Total	530 (91.54%)	49 (8.46%)	579 (100%)

Abbreviations: DPOAE, distortion product otoacoustic emission; TEOAE, transient evoked otoacoustic emission.

noninvasive and objective manner, independent of nerve action potentials.[9]

In this study, a comparison between the pass/refer rates of neonates in TEOAE and DPOAE showed that the majority of neonates passed and a minority were referred in both procedures. The pass index for TEOAE was higher than for DPOAE.

In the national literature, the pass index ranged between 85 and 96.78% using TEOAE as the screening procedure. Some studies have corroborated this finding and others did not.[25–28] When the DPOAE was used as the screening procedure, authors reported that pass rate ranged from 66.7 to 93.5%, and this variation may be due to the population studied and the protocols used.[29]

In the literature, few studies compared the pass rates using the two procedures in the same population. Unlike the results obtained in this study, researchers used these two procedures, TEOAE and DPOAE, and found a pass rate of 71% to TEOAE and 97% to DPOAE.[30] A possible explanation for a higher pass rate in TEOAE than in DPOAE could be the difficulty in adapting the probe in the acoustic meatus of the patient, which could result in failure to capture the response due to the influence of external and internal noise.

Although it presents itself as a fast examination in an infant's case, it should be noted that there are difficulties in test performance, for example, stopping the test when the baby is restless.[23] The literature also reports the influence of noise on DPOAE as the major obstacle to record responses at low frequencies.[24,31]

The correlation of the two types of emissions was positive, strong, and significant. Although few studies compared and correlated these two procedures, the results corroborate the findings of this study.[22,23,30,32]

One study showed a significant correlation between the results of TEOAE and DPOAE and demonstrated the reliability of the two types of otoacoustic emissions in the accomplishment of newborn hearing screening in preterm neonates.[30,31,33]

A comparison of TEOAE and DPOAE in preschool children showed that the signal-to-noise ratio in TEOAE was smaller than in DPOAE, and this difference was significant for low frequencies and not significant for high frequencies. The authors reported that this was the first study to focus on the comparison of the two methods and concluded that both are equivalent and effective and recommended for this population assessment.[7,22]

Table 3 TEOAE and DPOAE pass/refer results considering the ear

TEOAE	DPOAE			
	RE		LE	
	Pass	Refer	Pass	Refer
RE				
Pass	548 (94. 64%)	15 (2. 59%)	–	–
Refer	4 (0. 69%)	12 (2. 07%)	–	–
LE				
Pass	–	–	547 (94.47%)	12 (2.07%)
Refer	–	–	2 (0.34%)	18 (3.1%)

Abbreviations: DPOAE, distortion product otoacoustic emission; LE, left ear; RE, right ear; TEOAE, transient evoked otoacoustic emission.

Table 4 Analysis of the correlation of TEOAE and DPOAE

Variable correlated	Sample (*n*)	Correlation coefficient (*r*)	Significance (*p*)
TEOAE × DPOAE (RE)	579	+0.562	<0.001[a]
TEOAE × DPOAE (LE)	579	+0.711	<0.001[a]
TEOAE × DPOAE (bilateral)	579	+0.538	<0.001[a]

Abbreviations: DPOAE, distortion product otoacoustic emission; LE, left ear; RE, right ear; TEOAE, transient evoked otoacoustic emission.
[a]Significant.

The transient otoacoustic emissions are faster and better assess the medium-frequency range, and the distortion products are frequency-specific and better assess high frequencies.[23]

The most recommended and most used technique in neonatal hearing screening programs is the TEOAE; however, due to frequency specificity of DPOAE, researchers are interested in comparing their results with those of TEOAE.[24]

Given the above, the type of otoacoustic emissions has advantages and disadvantages, but the association of both procedures would allow a better sensitivity and specificity of neonatal hearing screening.

Conclusion

In this study comparing TEOAE and DPOAE, a significant correlation was found between the two procedures, which demonstrates the reliability of the methods employed.

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