Clinical Study

Transiently Evoked Otoacoustic Emissions in Children with Otitis Media with Effusion

Dimitris G. Balatsouras,1 George Koukoutsis,1 Panayotis Ganelis,1 George S. Korres,2 Andreas Aspris,3 and Antonis Kaberos1

1 ENT Department, Tzanion General Hospital of Piraeus, Afentouli 1 and Zanni, 18536 Piraeus, Greece
2 ENT Department, Atticon University Hospital of Athens, 1 Rimini Street, Haidari, 12462 Athens, Greece
3 ENT Department, Nicosia General Hospital, Nechrou Avenue, Southeastern Nicosia, 1102 Cyprus, Greece

Correspondence should be addressed to Dimitris G. Balatsouras, dbalata@hotmail.com

Received 15 September 2011; Accepted 24 October 2011

Academic Editor: Jizhen Lin

Copyright © 2012 Dimitris G. Balatsouras et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Introduction. Otitis media with effusion is a common pediatric disease whose diagnosis is based on pneumatic otoscopy, pure-tone audiometry, and tympanometry. The aim of this study was to evaluate transiently evoked otoacoustic emissions in the diagnosis of otitis media with effusion as compared to tympanometry.

2. Material and Methods

A group of 38 children with bilateral otitis media with effusion was studied. Twenty-one of them were male and 17 female, ranging in age from 4 to 15 years, with a mean age of 8.3 years. Forty normal children of similar age and sex were used as controls. Both patients and controls underwent clinical otologic and audiological evaluation including medical history, pneumatic otoscopy, tympanometry, and standard
pure-tone audiometry. The diagnosis of otitis media with effusion was established when findings in at least three of them were positive. This was used as the gold standard for the comparison of the diagnostic accuracy of TEOAEs, tympanometry, or their combination.

Conventional pure-tone audiometry was conducted in a standard sound proof booth, using a two-channel Amplaid 455 audiometer and earphones. Standard audiometric procedures were applied and the pure-tone thresholds of each ear at frequencies of 0.25, 0.5, 1, 2, 3, 4, and 8 kHz were measured. Subjects were considered to have a hearing loss if any threshold between 250 and 8000 Hz exceeded 20 dB HL. When air conduction thresholds were out of normal hearing range, bone conduction thresholds were obtained.

Standard single-frequency tympanometry was performed with an Amplaid 770 clinical admittance meter, using a single frequency 85 dB SPL (sound pressure level) tone set at 226 Hz. The range of ear canal pressure was +400 to −600 daPa. The American Speech-Language-Hearing Association guidelines were used to determine if a tympanogram was considered abnormal [6]: (1) static admittance less than 0.3 mmho; (2) an equivalent ear canal volume greater than 1.0 cm³ when accompanied by a flat tympanogram; (3) tympanometric width greater than 200 daPa.

TEOAEs were further performed in all patients and controls, using a DP Echoport ILO 292 Otodynamics analyzer connected to a portable personal computer. The acoustical stimulation, the data recording, and the data analysis were produced automatically with the aid of this system. Testing was performed in a sound-treated room using a standard ILO adult probe with disposable tips. Meatus response monitoring was used to check fitting conditions of the probe. The noise rejection level at the probe tip was set to 47 dB. Stimuli were half-sinusoidal clicks of 100 µsec duration. The nonlinear method of recording was used, allowing the phase-locked cochlear component of the response to be measured. The recording bandwidth was set between 0.75 to 5 kHz, stimulus intensity was approximately 80 dB, and repetition rate was 50 stimuli/sec. The numbers of responses accepted and rejected by artefact rejection were displayed and updated during averaging. The test was concluded after 260 total sweeps had been recorded. Details of this procedure are reported elsewhere [7]. The “pass” criteria were signal-to-noise ratio ≥ 6 dB, in four of five 1/2 octave frequency bands at 1, 1.5, 2, 3, and 4 kHz [8].

3. Results

Thirty-six patients were successfully tested with standard pure-tone audiometry. The remaining two were younger subjects who failed to respond adequately. However, pneumatic otoscopy, tympanometry, and TEOAEs were performed to both of them successfully, and the diagnosis of otitis media with effusion was established. Audiometry was successfully completed in all the subjects of the control group. Mean pure-tone thresholds exceeded 20 dB HL for the lower and middle frequencies in the group of children with otitis media with effusion, whereas mean values lower than 20 dB HL were found in the control group across all the examined frequencies (Table 1). In 72 ears (94.7%) of the group of patients the tympanograms were abnormal and in the remaining 4 (5.3%) they were normal. In 70 ears (87.5%) of the control group tympanograms were normal, whereas in the remaining 10 ears (12.5%) tympanograms were abnormal. The sensitivity of tympanometry was 94.7% and its specificity was 87.5%. In Table 2, the results for sensitivity, specificity, positive predictive value, and negative predictive value, with their corresponding 95% confidence intervals, are shown.

In 51 ears of the patients (67.1%) otoacoustic emissions were absent. In the remaining 25 ears (32.9%) the mean emission amplitude was reduced, compared to the mean value of the control group (Table 1). In 68 of the 80 ears of controls clear TEOAEs were recorded. Comparison of signal-to-noise ratios by independent sample t-test between the two groups showed statistically significant differences. In all cases the values of the patients were lower than the mean value of the controls. In this comparison only the ears with present emissions were included from both groups. The sensitivity of TEOAEs was 67.1% and its specificity was

### Table 1: Means and levels of statistical significance (P) of pure-tone thresholds and signal-to-noise ratios of transiently evoked otoacoustic emissions (TEOAEs), comparing the ears of patients and the ears of controls.

| Frequencies (kHz) | Pure-tone thresholds | Signal-to-noise ratios (TEOAEs) |
|-------------------|----------------------|---------------------------------|
|                   | Patient ears (N = 72) | Control ears (N = 80) | P | Patient ears (N = 25) | Control ears (N = 68) | P |
| 0.25              | 30.4                 | 12.5               | <0.001 | nm⁺                  | nm               | nm |
| 0.5               | 28.7                 | 9.4                | <0.001 | nm                  | nm               | nm |
| 1.0               | 23.3                 | 8.8                | <0.001 | 5.8                 | 4.6              | <0.01 |
| 1.5               | nm                   | nm                 | nm     | 11.2                | 6.3              | <0.001 |
| 2.0               | 24.7                 | 12.0               | <0.001 | 17.4                | 7.4              | <0.001 |
| 3.0               | 19.8                 | 14.3               | <0.01 | 16.1                | 8.3              | <0.001 |
| 4.0               | 17.5                 | 15.3               | ns¹    | 16.8                | 9.0              | <0.001 |
| 8.0               | 13.4                 | 14.3               | ns     | nm                  | nm               | nm |

⁺ not measured; ¹ non significant.
It has been reported that transiently evoked otoacoustic emissions (TEOAEs) can practically interfere with middle-ear disease. Glattke et al. [10] found that a type B tympanogram impeded measurement of transiently evoked otoacoustic emissions, whereas type A of tympanogram was associated with present emissions. These authors too encouraged further diagnostic accuracy (Table 2). The screening test efficiency values (overall number of true positives and true negatives divided by the total number of ears tested) for TEOAEs, tympanometry, and their combination were, respectively, 76.2%, 91%, and 95.5%.

### 4. Discussion

TEOAEs are a valuable screening tool for hearing impairment, although neither information about the degree or configuration of hearing loss is provided, nor is differential diagnosis between sensorineural and conductive hearing loss possible [3]. TEOAEs are transmitted from the cochlea through the ossicles and tympanic membrane and measured in the external ear canal. Therefore, any middle-ear or outer-ear disorder can practically interfere with transiently evoked otoacoustic emission transmission [5]. It has been reported that artificial manipulation of the middle-ear compliance causes a decrease in the response levels of the otoacoustic emissions [9]. Glattke et al. [10] found that a type B tympanogram precluded recording of transiently evoked otoacoustic emissions. Even the presence of negative tympanogram was found to be associated with present emissions. However, Hall III et al. [14] proposed that otoacoustic emission testing should be performed even in the presence of middle-ear disease. Koike and Wetmore [15] found that the status of the middle ear greatly affected transiently evoked otoacoustic emission measures, which was most significant with flat tympanograms, mainly indicative of reduced tympanic membrane mobility and the presence of middle-ear effusion. These authors too encouraged the routine use of transiently evoked otoacoustic emission testing.

In several reports, high failure rates of TEOAEs in cases with flat tympanograms were found. Ho et al. [16] reported failure rates approaching 71-72% in ears with middle-ear effusion and abnormal tympanograms. These authors found good agreement between tympanometry failure and transiently evoked otoacoustic emission failure for the 3- to 5-year-old group of children. Similar rates were found in another report of transiently evoked otoacoustic emission measurements [17], and our rate of approximately 67% failure is in accordance with them. In most of the previously mentioned reports the Liden/Jerger tympanogram classification system was used. Fortunately, quantitative analysis is now possible and objective criteria may be used [6], as in the present study. Dragi ˇcevi´c et al. [18] have also used TEOAEs as a hearing screening tool in children with OME, before and after surgery. According to these authors, preoperative TEOAEs were absent in 93.5% of the ears, but were significantly improved postoperatively.

When applying tympanometry and TEOAEs in hearing screening, the sensitivity and specificity of both tests should be considered. The problem in such studies is the absence of a gold standard, as would be the findings of myringotomy in the examined ears. However, this is not possible in most cases, and several authors have used tympanometry as the gold standard, due to its high sensitivity to middle-ear disorders. Taylor and Brooks [19] obtained by this method 60% sensitivity and 91% specificity of TEOAEs compared to tympanometry. Recently, Śliwa et al. [20] combined three diagnostic methods, automated 4-frequency audiometry, TOEAEs and tympanometry, in hearing screening of school children. The authors used conventional tone audiometry as the reference and found high specificity and low sensitivity values for all the tests, but combination of tympanometry and TEOAEs yielded 60% sensitivity and 94% specificity, whereas addition of automated 4-frequency audiometry further improved sensitivity to 70%.

In our study, we used the combination of positive history, positive otoscopic appearance by pneumatic otoscopy, abnormal tympanographic findings, and elevated threshold in pure-tone audiometry as a gold standard to establish diagnosis. According to these, the sensitivity of tympanometry was as high as 96% and its specificity was 85%. When calculating the sensitivity of TEOAEs according to the “pass” criterion, a rate of 67% was obtained, whereas specificity approached 85%. However, in the remaining ears which obtained the “pass” criterion, transiently evoked otoacoustic emission measurements were lower than controls, at a statistically significant level. It appears, thus, that the sensitivity of TEOAEs in otitis media with effusion is

### Table 2: Estimates for the sensitivity, specificity, positive predictive value, and negative predictive value of transiently evoked otoacoustic emissions (TEOAEs), tympanometry, and the combined use of both tests. Numbers in parentheses provide estimates of the 95% confidence intervals.

| Statistical measures | TEOAEs | Tympanometry | TEOAEs and tympanometry |
|----------------------|--------|--------------|------------------------|
| Sensitivity (%)      | 67.1 (55.2–77.1) | 94.7 (86.3–98.3) | 98.6 (91.8–99.9) |
| Specificity (%)      | 85.0 (74.8–91.6)  | 87.5 (77.7–93.5) | 92.5 (83.8–96.9)  |
| Positive predictive value (%) | 80.9 (68.7–89.3) | 87.8 (78.2–93.6) | 92.5 (83.9–96.9) |
| Negative predictive value (%) | 73.1 (62.7–81.5) | 94.5 (86.0–98.2) | 98.6 (91.7–99.9) |

85% (Table 2). Combination of TEOAEs and tympanometry yielded sensitivity 98.6% and specificity 92.5%, improving further diagnostic accuracy (Table 2). The screening test efficiency values (overall number of true positives and true negatives divided by the total number of ears tested) for TEOAEs, tympanometry, and their combination were, respectively, 76.2%, 91%, and 95.5%.
high, whenever absolute values of TEOAE measurements are considered and not only a “pass” criterion. Specificity is lower, because TEOAEs are also influenced by inner-ear disease, although this is not quite common in the age group of our study.

Finally, a comment on pure-tone thresholds in standard audiometry should be made. In several reports, mean pure-tone thresholds between 15 and 20 dB HL have been found [21]. In our study mean thresholds were approximately 20–25 dB HL in the standard frequencies of 0.5, 1, 2 and 3 kHz. It appears, thus, that an audiometric criterion of 20 dB would be appropriate to separate normal ears from ears with absent or reduced transiently evoked otoacoustic emissions.

5. Conclusion

From this study, it may be concluded that TEOAEs should be included in the diagnostic workup of otitis media with effusion. Their sensitivity in diagnosing middle-ear disease is high when quantitative measures are used, whereas their specificity is lower, because abnormal results may also be found in cases with inner-ear disease. For this reason, TEOAEs should always be used along with tympanometry, because a more meaningful interpretation of transiently evoked otoacoustic emission measures in conjunction with tympanometry results is possible.

References

[1] M. L. Casselbrandt and E. M. Mandel, “Epidemiology,” in Evidence-Based Otitis Media, R. M. Rosenfeld and C. D. Bluestone, Eds., pp. 117–138, B. C. Decker, Ontario, Canada, 1st edition, 1999.

[2] J. Jerger, “Clinical experience with impedance audiometry,” Archives of Otolaryngology, vol. 92, no. 4, pp. 311–324, 1970.

[3] D. T. Kemp, S. Ryan, and P. Bray, “A guide to the effective use of otoacoustic emissions,” Ear and Hearing, vol. 11, no. 2, pp. 93–105, 1990.

[4] S. Korres, T. Nikolopoulos, E. Ferekidis, Z. Gotzamanoglou, A. Georgiou, and D. G. Balatsouras, “Otoacoustic emissions in universal hearing screening: which day after birth should we examine the newborns?” Journal for Oto-Rhino-Laryngology and Its Related Specialties, vol. 65, no. 4, pp. 199–201, 2003.

[5] S. W. Yeo, S. N. Park, Y. S. Park, and B. D. Suh, “Effect of middle-ear effusion on otoacoustic emissions,” Journal of Laryngology and Otology, vol. 116, no. 10, pp. 794–799, 2002.

[6] American Speech-Language-Hearing Association, Guidelines for Audiologic Screening, ASHA, Rockville, Md, USA, 1997.

[7] S. G. Korres, D. G. Balatsours, C. Economou, E. Ferekidis, D. Kandiloros, and G. Adamopoulos, “Effect of the number of averaged responses in transient evoked otoacoustic emissions on the results of neonatal hearing screening,” Audiology, vol. 39, no. 6, pp. 293–299, 2000.

[8] S. Korres, D. Balatsours, E. Ferekidis, E. Gkoritsa, A. Georgiou, and T. Nikolopoulos, “The effect of different ‘pass-fail’ criteria on the results of a newborn hearing screening program,” Journal for Oto-Rhino-Laryngology and Its Related Specialties, vol. 65, no. 5, pp. 250–253, 2003.

[9] M. B. Trine, J. E. Hirsch, and R. H. Margolis, “The effect of middle ear pressure on transient evoked otoacoustic emissions,” Ear and Hearing, vol. 14, no. 6, pp. 401–407, 1993.

[10] T. J. Glattke, I. A. Paftis, C. Cummiskey, and G. R. Herer, “Identification of hearing loss in children and young adults using measures of transient otoacoustic emission reproducibility,” American Journal of Audiology, vol. 4, pp. 71–86, 1995.

[11] B. A. Prieve, L. Calandruccio, T. Fitzgerald, A. Mazevski, and L. M. Georgantas, “Changes in transient-evoked otoacoustic emission levels with negative tympanometric peak pressure in infants and toddlers,” Ear and Hearing, vol. 29, no. 4, pp. 533–542, 2008.

[12] J. J. Owens, M. J. McCoy, B. L. Lonsbury-Martin, and G. K. Martin, “Otoacoustic emissions in children with normal ears, middle ear dysfunction, and ventilating tubes,” American Journal of Otolaryngology, vol. 14, no. 1, pp. 34–40, 1993.

[13] S. S. Choi, I. A. Paftis, G. H. Zalal, G. R. Herer, and K. M. Patel, “Clinical applications of transiently evoked otoacoustic emissions in the pediatric population,” Annals of Otolaryngology—Head and Neck Surgery, vol. 108, pp. 132–138, 1999.

[14] J. W. Hall III, J. E. Baer, P. A. Chase, and M. K. Schwaber, “Clinical application of otoacoustic emissions: what do we know about factors influencing measurement and analysis?” Otolaryngology—Head and Neck Surgery, vol. 110, no. 1, pp. 22–38, 1994.

[15] K. J. Koike and S. J. Wetmore, “Interactive effects of the middle ear pathology and the associated hearing loss on transient-evoked otoacoustic emission measures,” Otolaryngology—Head and Neck Surgery, vol. 121, no. 3, pp. 238–244, 1999.

[16] V. Ho, K. A. Daly, L. L. Hunter, and C. Davey, “Otoacoustic emissions and tympanometry screening among 0–5 year olds,” Laryngoscope, vol. 112, no. 3, pp. 513–519, 2002.

[17] P. Koivunen, M. Uhari, K. Laitakari, O. P. Alho, and J. Luotonen, “Otoacoustic emissions and tympanometry in children with otitis media,” Ear and Hearing, vol. 21, no. 3, pp. 212–217, 2000.

[18] D. Dragicevič, L. Vlaški, Z. Komazec, and R. M. Jovič, “Transient evoked otoacoustic emissions in young children with otitis media with effusion before and after surgery,” Auris Nasus Larynx, vol. 37, no. 3, pp. 281–285, 2010.

[19] C. L. Taylor and R. P. Brooks, “Screening for hearing loss and middle-ear disorders in children using TEOAEs,” American Journal of Audiology, vol. 9, no. 1, pp. 50–55, 2000.

[20] L. Śliwa, S. Hatzopoulos, K. Kochanek, A. Piłka, A. Senderski, and P. H. Skarzyński, “A comparison of audiometric and objective methods in hearing screening of school children. A preliminary study,” International Journal of Pediatric Otorhinolaryngology, vol. 75, no. 4, pp. 483–488, 2011.

[21] L. L. Hunter, R. H. Margolis, and G. S. Giebink, “Identification of hearing loss in children with otitis media,” Annals of Otolaryngology—Rhinology & Laryngology Supplement, vol. 163, pp. 59–61, 1994.