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Relationship Between Subjective and Objective Hearing Tests in Children with Middle Ear Pathology

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Abstract: Otoacoustic Emissions are considering to orginate from movement of outer hear cells and to be transmited in a retrograde fashion through ossicular chain and tympanic membrane to the external auditory meatus. Thus, before stable evoked emission can be recorded it is essential that the middle ear conductive apparatus functioning correctly.

In this paper we investigated the alterations in the click evoked otoacoustic emissions parameters and relationship between subjective and objective hearing test. The study comprised: 30 otologically healthly children and 95 children with Serous Otitis Media (SOM) and hyperthropic adenoids, aged 3 to 11 yars (average age 4.2). In each child we performed: tympanometric tests, pure-tone audiometry (was determined where possible) and Click Evoked Otoacoustic Emisson. All audiometric examination were carried out as: initial examinations – follow up examinations two weeks after adenotomy and remote follow up examinations three months after surgery.

Because of average age in 70 children (73.7%) reliable evaluation of hearing acuity using routine tests of conventional audiometry was impossible. Within all 190 ears in initial tests EOAE could be registered only in 74 ears (38.9%), but only in 44 ears (59.5%) it had correct values, whereas in the rest of 30 ears (40.5%) had reduced parameters. In the rest of 116 ears (61.1%) with the lack of EOAE in the initial tympanometric examinations we observed pathological tympanograms B and C and significantly increased middle ear pressure in daPa and mean values of PTA. Improvement of hearing in 93.9% of audiometric tests as well as normalising the tympanometric tests we confirm by, increasing cochlear emissions with higher amplitude of 21,20 dBSPL and higher reproducibility 92.28%.

Application of batery subjective and objective hearing tests in ears which display conductive hearing loss in useful not only for evaluation of hearing acuity, but also for monitoring of the efficacy of the treatment, especially in very young children.

Zusammenfassung: *Die Beziehung zwischen subjektiven und objektiven Hörtests bei Kindern mit Mittelohrerkrankung*. Otoakustische Ausstrahlungen stammen, nach allgemeiner Annahme, aus der Bewegung der äußeren Haarzellen und werden retrograd über Knochen-

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leitung und Trommelfell zum äußeren Gehörgang weitergeleitet. Für die Registrierungsmöglichkeit von evozierten otoakustischen Ausstrahlungen ist es deshalb wesentlich, daß die Leitung durch das Mittelohr ungestört ist. In diesem Beitrag untersuchten wir die Veränderungen in den Parametern von durch ein Klickgeräusch evozierten otoakustischen Ausstrahlungen und deren Beziehung zu subjektiven und objektiven Hörtesten. Die Untersuchung umfaßte 30 hörgesunde Kinder und 95 Kinder mit seröser Mittelohrentzündung und vergrößerten Mandeln im Alter von 3-11 Jahren (im Mittel 4,2 Jahre). Bei jedem Kind wurden Trommelfell-Teste gemacht, wie ebenso eine Testung des Hörens von reinen Tönen und von klick-evozierten otoakustischen Ausstrahlungen. Alle audiometrischen Untersuchungen wurden wiederholt: Eine Anfangsuntersuchung und eine Nachuntersuchung zwei Wochen nach der Entfernung der Rachenmandeln und eine spätere Nachuntersuchung drei Monate nach der Operation. Wegen des geringen mittleren Alters waren bei 70 Kindern (73,7%) verläßliche Bewertungen der Hörfähigkeit mit den üblichen audiometrischen Testen nicht möglich. Bei dem Gesamt von 190 Ohren konnten otoakustische Ausstrahlungen nur bei 74 Ohren (38,9%) gemessen werden, aber nur bei 44 Ohren (59,5%) ergaben sich korrekte Werte, während beim Rest von 30 Ohren (40,5%) die Meßwerte reduziert waren. Beim Rest von 116 Ohren (61,1%) mit dem Fehlen von otoakustischen Ausstrahlungen bei der anfänglichen Trommelfellmessung beobachteten wir pathologische Tympanogramme B und C, signifikant erhöhten Mittelohrdruck und mittlere Werte für die Hörschärfe. Die Besserung des Hörens bei 93,9% in den audiometrischen Tests wie ebenso die Normalisierung der tympanometrischen Teste korrespondierten mit ansteigenden otoakustischen Ausstrahlungen mit höherer Amplitude von 21,20 dBSPL und höherer Reproduzierbarkeit von 92,28%. Folgerungen: Die Anwendung von subjektiven und objektiven Hörtesten bei Ohren, die Hörverlust zeigen, ist nicht nur für die Bewertung der Hörfähigkeit nützlich, sondern ebenso für die Einschätzung der Wirksamkeit der Therapie, insbesondere bei sehr jungen Kindern.

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Introduction

Otoacoustic emission (OAE) generated by the cochlea must be transmitted via the middle ear to the site where it can be recorded, that is, to the external ear canal. OAE may be reduced or cannot be recorded if sound transmission both into and out of the cochlea through the middle ear is impaired (Owens et al. 1992; Bonfils et al. 1988; Reroń and Olszewski 1987; Probst et al. 1987; Whitehead et al. 1996). Therefore, evoked otoacoustic emission (EOAE) is more and more frequently used as a physiological test for evaluation of the peripheral part of the hearing organ (Owens et al. 1992; Hunter et al. 1994; Lonsbury-Martin et al. 1994). Although Serous Otitis Media (SOM) has been recognised since the early 19th century (and possible even before the seventeenth century) (Gibbin 1994) and in detail described in Schmiegielow's textbook of 1912, is still one of the most common diseases of the early childhood leading to moderate or severe hearing loss which significantly impairs not only speech and language development but also determines social and intellectual development of the child. Aetiopathogenesis of Serous Otitis Media is multifactoral and complex. However, according to Gates et al. (1990) as well as Paparella and Schachern (1994) and Gates (1994) hypertrophy of adenoids as a primary factor in pathogenesis of SOM has been known for a long time. It can result in obstruction of the Eustachian tubes both mechanical

and functional leading to conductive hearing loss of various degree, which in turn, can affect registration of click evoked otoacoustic emissions (EOAEs).

The purpose of our study was:

1. Evaluation of the influence of the middle ear pathology on detectability and parameters of EOAEs, that is, on the size of their amplitude and reproductibility.
2. Assessment of the relation between EOAE spectrum analysis and audiogram, as well as, between the size of otoemissions amplitude and PTA values.
3. Evaluation of usefulness of EOAEs registration for monitoring of the efficacy of the therapeutic management.

Material and Methods

The study included a group of 95 children aged 3 to 11 years (mean age 4.2 years) hospitalised in the ENT Department of the University Hospital in Cracow because of serous otitis media (SOM) and hypertrophic adenoids who underwent adenotomy because of dysfunction of the Eustachian tubes and conductive hearing loss of various degree.

The other group comprised 30 otologically healthy children (n = 60 ears) the same age range with no past history of severe or chronic diseases of ears or use of ototoxic drugs, with normal results of otological examinations (normal otoscopy, and middle ear pressure). Pure tone audiometry in all children of this group revealed hearing threshold values 5 to 10 dBnHL in frequency range of 250 to 8000 Hz.

In each child, classification of hearing loss was based on the results of clinical and audiometric examinations. Careful audiometric examinations were carried out such as: pure tone audiometry (if possible), tympanometry tests, and registration of click evoked otoacoustic emissions (EOAE). In pure tone audiometry, hearing threshold values for each ear were established and then pure tone average (PTA) values for frequencies of 500, 1000, 2000 and 4000 Hz were calculated. In tymanometric tests carried out using apparatus Madsen Zodiac-901, the pressure in the tympanic cavity was taken in daPa, and tympanometric shapes were classified according to Jerger's classification into types: A, B and C. EOAEs were elicited by the 80 dB SPL clicks generated by Otodymamics Analyser ILO-92.

In assessment of EOAEs, the following parameters were taken into account:

1. Presence or absence of otoemissions of any frequency.
2. In evoked otoemissions we analysed: their amplitude in dBSPL, percentage of their reproductibility, intensity of frequencies in their spectrum.

Audiometric examinations were carried out as: initial examinations – Stage I, follow up examinations two weeks after adenotomy – Stage II, and remote follow up examinations three months after adenotomy – Stage III.

The results obtained underwent statistical analysis using packet of computer programmes SAS. Quality variables in tympanometry were analysed by independence test chi2. Quantity variables, that is, results of pure-tone audiometry, the middle ear pressure, amplitude and reproductibility of EOAEs were studied using

the variable analysis test. Analysis of relationship between subjective and objective examinations was carried out using correlation methods based on Pearson's linear correlation coefficient. An appropriate test of differences from '0' was performed for each parameter.

Results

Stage I, that is initial examination before the beginning of treatment, involved 95 children, Stage II – 50, and Stage III, that is remote follow up examination – 35 children. The control group comprised 30 otologically healthy children. The results obtained from 420 ears were statisticaly analysed. All children with the middle ear pathology were classified according to tympanogram shape into three groups: A, B and C. Because of the functional condition of the middle ear, this classification was used in all stages of the examination.

Table 1. Mean values in: middle ear pressure pure-tone average (PTA) amplitude and reproduction of EOAE in consecutive stages of examination.

	Examination stage		Number of ears	Type of tympanometry			Control group	Significance
				A	C	B	N = 60	
A	Middle ear pressure (in da Pa)	I	190	–41.46	–152.53	316.24	28.40	$p < 0.001$
		II	100	40.00	148.46	276.90		$p < 0.001$
		III	70	28.63	121.32	235.83		$p < 0.001$
B	PTA (dB HL)	I	115	9.73	14.16	23.92	5.00	$p < 0.001$
		II	62	8.73	12.15	18.15		$p < 0.001$
		III	56	7.12	11.05	18.98		$p < 0.001$
C	Amplitude of EOAE (dB SPL)	I	74	15.38	9.91	8.07	22.80	$p < 0.001$
		II	72	17.57	11.47	9.25		$p < 0.001$
		III	58	21.20	16.05	12.00		$p < 0.001$
D	% of EOAE reproduction	I	74	84.28	78.15	67.39	94.80	$p > 0.01$
		II	72	84.26	80.10	76.00		$p > 0.01$
		III	58	92.28	81.43	77.50		$p > 0.05$

Analysing mean values of the middle ear pressure and mean values of PTA (Table 1, A and B), significant differences were observed both in tympanogram type and in particular stages of examination. The lowest values of negative middle ear pressure of 316.24 daPa were registered in initial examination in children with flat tympanogram B with the highest values of PTA of 23.92 dBnHL. In the course of functional normalisation of the middle ear, these parameters show gradual improvement, however in 12 ears in remote follow up examinations in Stage III negative pressure of 235.83 daPa is still observed, and mean value of PTA is still high of 18.98 dBnHL. These 6 children had ventilation tube insertion.

In initial examination, EOAEs were registered only in 74 ears (38.9%) of 190 examined ears (Table 2). Correct responses with relatively high amplitude of 15.38

Table 2. Percent of EOAE in consecutive stages of examination in relation to type of tympanometry.

Examination stage	Number of ears	% of EOAE	Type of tympanometry			Total % lack of EOAE
			A	C	B	
I	190	38.90	59.5	36.5	4.0	61.1
II	100	72.0	70.14	18.5	11.1	28.0
III	70	80.0	75.90	13.8	10.3	20.0
Control group	60	100.0	100.0	–	–	

dB SPL and reproductibility of 84.28% were registered only in 44 ears (59.5%) with tympanogram A, whereas in the rest of 30 ears (40%) EOAEs had a decreased amplitude (8.07–9.91 dB SPL) and lowered percentage of reproducibility (67.30–78.15%). EOAEs were not registered in 116 ears (61.1%) – 89 of them had tympanograms B, 24 – tympanograms C and 3 – correct tympanograms A.

Analysing mean values of amplitude and reproducibility of EOAEs in particular groups of children and consecutive stages of examination (Table 1, C and D), it can be observed that the values of EOAEs change in relation to the mean values of hearing loss in PTA and the values of the middle ear pressure. Amplitude and reproductibility are the lowest in Stage I of examination of children with tympanogram B, and in consecutive stages these parameters increase gradually, achieving the highest values in remote follow up examinations in which mean amplitude for children with tympanogram A is 21.20 dBSPL and reproductibility 92.28%. These values were similar to those obtained in the control group in which they achieved 22.80 dBSPL and 94.80%, respectively.

Table 3. Values of Persons linear correlation coefficient between mean values of: PTA and amplitude of EOAE in consecutive stages of examination.

Examination stage	Type of tympanogramy		
	A	C	B
I	0.17	0.15	0.14
II	0.38	0.18	0.15
III	0.81	0.56	0.38
Control group	0.96**	–	–

** $p < 0.01$

The studies of the relationship between the amplitude size of EOAEs and average hearing loss in PTA were carried out using Pearson's linear correlation coefficient (Table 3). It can be observed that the strongest relationship between the parameters mentioned above occurred in remote follow up examinations in tympanograms A and C, for which the correlation coefficient is between 0.6–0.8. It denotes a strong relationship between mean values of hearing loss in PTA and amplitude size in EOAEs. However, despite its strength, this relationship has no statistical significance.

Table 4. Values of Persons linear correlation coefficient between threshold values for 2000 and 4000 Hz in pure tone – audiometry and otoemission spectrum.

Examination stage	Type of tympanogram					
	A		C		B	
	2000 Hz	4000 Hz	2000 Hz	4000 Hz	2000 Hz	4000 Hz
I	1.00**	0.98*	0.44	0.37	0.18	0.11
II	0.21	0.22	0.18	0.51	0.63	0.50
III	0.85*	0.92**	0.63**	0.50*	0.44	0.63*

* $p < 0.05$; ** $p < 0.01$

The relationship between threshold values in pure tone audiometry for frequencies 1000, 2000, 4000 Hz and frequencies in otoemission spectrum was also studied (Table 4). The values of correlation coefficient are statistically significant mainly for frequencies 2000 and 4000 Hz especially in Stage I for tympanograms A and Stage III for all types of tympanometry. In Stages I and II the values of correlation coefficient in tympanometry B and C are very low indicating a slight relationship between threshold values in pure tone audiometry and frequencies in otoemission spectrum.

Discussion

Numerous investigations both on animals and people show that in order to register stable evoked otoemission which is an index of the function of cochlear micromechanisms, functional condition of the middle ear must be correct. Therefore, according to Owens et al. (1992), Proschel and Eyscholdt (1993), Trine et al. (1993) it is essential to supplement EOAE registration with tests evaluating functional condition of the middle ear, especially with tympanometry.

According to Erving et al. (1991), Fuse et al. (1993), Lonsbury-Martin et al. (1994) Reroń and Olszewski (1997) they confirm usefulness of classification of examination with EOAE in relation to the type of tympanometry, especially in the middle ear pathology. As early as 1988, Bonfils et al. found that frequency of EOAE registration decreases in relation to an increase of mean audiometric threshold. Later this was confirmed by Prieve et al. (1993), Owens et al. (1992), Trine et al. (1993) as well as by Reroń and Olszewski (1997), and Reroń et al. (1997).

Significant relationship obtained in our present investigations between frequency of registration of EOAEs and their parameters and the middle ear pressure as well as mean values of hearing loss confirm the findings of the authors above. The possible relation between audiogram and spectrum analysis of EOAEs was already suggested by David Kemp in 1990 but it was not confirmed by clinical investigations. Collet et al. (1991) confirmed the relationship between spectrum analysis of EOAEs and sensory-neural hearing impairment, the most intensively expressed in the range of high frequencies. Similarly, Prieve et al. in 1993 suggested that in frequency 2 to 4 KHz, registration of EOAEs, especially in high frequencies, enables to differentiate individuals with normal hearing from those

with hearing loss. This differentiation is ineffective, however, for frequencies 1 KHz and almost zero for 500 Hz. The results of our present investigations are in agreement with those obtained by the authors above, since the most intensively expressed and the most considerable relationship between the threshold values and frequencies in spectrum analysis of EOAEs was observed for frequencies 4000 and then 2000 Hz in children with normal hearing. The values of correlation coefficient for the remaining frequencies were so low that hardly any relationship between the parameters discussed could be found. However, of great importance seems to be the relationship obtained in our present studies between the amplitude of EOAEs and mean values of PTA expressed by high values of Pearson's linear correlation coefficient, despite the lack of statistical significance. The lack of this significance may be caused by insufficient number of children included in all stages of investigations. Nevertheless, the relationship obtained suggests that both power spectrum of EOAEs, as well as the size of their amplitude may provide useful information about audiometry shape.

Conclusions

1. The number of EOAEs in children with conductive hearing loss of various degree shows statistically significant relation to the middle ear pressure and mean values of hearing loss expressed by PTA.
2. Even slight hearing impairment from 9 to 12 dB HL in Stage I of our examinations reduces considerably amplitude and percentage of reproducibility of EOAEs.
3. Analysis of changes of EOAEs in particular stages of examinations confirms that their registration is a sensitive and useful tool in audiometric evaluation of conductive hearing loss in children, especially when a young age prevents from reliable subjective audiometry.
4. Usefulness of EOAE registration is also confirmed by:
   a) Considerable relationship between amplitude of EOAEs and mean values of hearing loss in PTA observed in children with tympanogram A and C in Stage I and III of examinations.
   b) Statistically significant relationship between threshold values for frequencies 2000 and 4000 Hz in pure-tone audiometry and frequencies in otoemission spectrum in Stage I with tympanogram A and Stage III of our investigations.
5. Normalisation of otoemission parameters during therapy and follow up examinations, as well as, the occurrence of clearly defined otoemissions evoked in remote follow up examinations confirm the usefulness of their registration for monitoring efficacy of the instituted treatment in children with conductive hearing loss.

References

Bonfils P, Piron JP, Uziel A, Pujol R (1988) A correlative study of Evoked Otoacoustic Emission properties and audiometric thresholds. Arch Otolaryngol 245: 53–56

Collet L, Veuillet E, Chanal JM, Morgon A (1991) Evoked Otoacoustic Emissions: Correlates between spectrum analysis and audiogram. Audiology 30: 164–172

Erwig H, Blomer E, Bauer HH (1991) Zur Evaluation Transitorisch Evozierter Otoakustischer Emissionen bei Kindern mit Tubenbelüftungsstörungen. Laryngorhinootologie 70(11): 635–640

Fuse T, Aoyagi M, Suzuki T, Koikey Y (1993) Clincal application of transiently Evoked Otoacoustic Emissions in screening for auditory function. Nippon-Jibinkoka-Gakkai-Kaimo 96(7): 1125–1132

Gates GA, Avery CA, Cooper JC, Prihoda TJ (1990) Chronic Secretory Otitis Media: Effects of Surgical Management. Ann Otol Rhinol Laryngol suppl 146, 99: 2–32

Gates GA (1994) Adenoidectomy for Otitis Media with Effusion. Ann Otol Rhinol Laryngol 103: 54–58

Gibbin KP (1994) Otological Considerations in the First 5 Years of Life. In: Mc Cormick B (ed.) Pediatric Audiology 0–5 Years. Whurr Publishers, London, pp 42–78

Hunter LL, Margolis RH, Giebink GS (1994) Identification of hearing loss in children with otitis media. Ann Otol Rhinol Laryngol 103: 59–61

Kemp DT, Ryan S, Bray P (1990) A guide to the effective use of Otoacoustic Emissions. Ear-Hear 11: 93–105

Lonsbury-Martin BL, Martin GK, Mc Coy MJ, Whitehead ML (1994) Otoacoustic Emissions testing in young children: Middle ear influences. The Amer J of Otology 15(suppl 1): 13–20

Owens JJ, Mc Coy MJ, Lonsbury-Martin BL, Martin GK (1992) Influence of otitis media on Evoked Otoacoustic Emissions in children. Seminars in hearing 13(1): 53–56

Paparella MM, Schachern P (1994) New Developments in Treating Otitis Media. Ann Otol Rhinol Laryngol 103: 7–10

Prieve BA, Gorga MP, Schmidt A, Neely S, Peters J, Schultes L, Jestead W (1993) Analysis of transient Evoked Otoacoustic Emissions in normal hearing and hearing impaired ears. J Acoust Soc Amer 93(6): 3308–3319

Probst R, Lonsbury-Martin BL, Martin GK, Coats AC (1987) Otoacoustic emissions in ears with hearing loss. Amer J Otolaryngol 8: 73–81

Proschel U, Eysholdt U (1993) Evoked Otoacoustic Emissions in children in relation to middle ear impedance. Folia Phoniatr 45: 288–294

Schmiegelow E (1912) Oretes Sygdome. Denmark Gyldendalske Boghandel, Nordisk Forlag, Copenhagen

Reroń E, Olszewski E (1997) Relationship between Evoked Otoacoustic Emissions and conductive hearing loss in children. Int Proceedings IFOS, Sydney Australia, t.I, 33–37

Reroń E, Olszewski E, Składzień J (1997) Otoakustyczna emisja ślimakowa (EOAE) u dzieci z dysfunkcją trąbki słuchowej. Otolaryngol Pol Suppl 22: 220–224

Trine MB, Hirsch JE, Margolis RH (1993) The effect of middle ear preassure on trasient Evoked Otoacoustic Emissions. Ear-Hear 14(6): 401–407

Whitehead ML, Lonsbury-Martin BL, Martin GK, Mc Coy MJ (1996) Clinical aspects of hearing: Otoacoustic Emissions: Animal models and clinical observations. In: Van de Water TR, Popper AN, Fay RR (eds.) Clinical aspects of hearing