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Effects of Exam Procedures on Transient Evoked Otoacoustic Emissions (TEOAEs) in Neonates

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Abstract

Debris in the ear canal and ear canal collapse in newborns have been shown to interfere with recording transient evoked otoacoustic emissions (TEOAEs). The purpose of this study was to prospectively evaluate the effects of two simple ear canal cleaning procedures on the TEOAE responses of normal newborns. Three hundred and sixteen ears were studied with an initial TEOAE followed randomly by either an otoscopic exam and refit procedure or a probe refit procedure. At the time of each procedure, any superficial debris attached to the otoscope or probe were removed before the second TEOAE was repeated with identical procedures. The study sample consisted of two equal groups of ears (otoscopic exam and refit). Each group initially had equal proportions of ears with no emission, a weak emission, or a robust emission. In the otoscopic group, 12 of 51 (24%) weak emissions converted to robust emissions, 10 of 53 (19%) no emissions converted to robust emissions, and 15 of 53 (28%) no emissions improved to weak emissions. In the refit group, 20 of 50 (40%) weak emissions converted to robust emissions, 13 of 57 (23%) no emissions converted to weak emissions, and 9 of 57 (16%) no emissions improved to weak emissions. Both the otoscopic viewing procedure and the refit procedure were effective in improving the TEOAE response.

Key Words: Newborns, otoacoustic emissions (OAEs), screen, transient evoked otoacoustic emissions (TEOAEs)

A number of studies have demonstrated that transient evoked otoacoustic emissions (TEOAEs) can be used to effectively screen newborns for congenital sensorineural hearing impairment (Bonfils et al, 1988; Stevens et al, 1990; White et al, 1990; Vohr et al, 1991; Maxon et al, 1995). It had previously been documented by Balkany et al (1978) that the external ear canal is partially filled with vernix in 100 percent of normal-term infants. We previously investigated the relationship between debris in the external ear canal and evoked otoacoustic emissions and determined that debris or obstruction due to vernix caseosa or external ear canal collapse had negative effects on emissions (Chang et al, 1992) Clearing the ear canal of the obstruction under direct vision improved the pass rate from 76 percent to 91 percent. These data indicated that whenever an infant did not pass the TEOAE, an examination of the ear canal and possible cleaning is warranted.

Routine cleaning of the ear canal, however, is a procedure that cannot be done easily in the nursery setting. Therefore, we attempted to identify an alternative method of relieving ear canal obstruction due to debris or collapse by re-evaluating the screening procedure. During routine screening with otoacoustic emission (OAE), a small acoustic probe fitted with a rubber tip is introduced into the ear canal and an attempt is made to obtain a snug fit. When changing tips between ears or patients, it was first observed that debris was frequently adhering to the probe and rubber tip. Second, it was observed that the ILO88 pediatric probe is the same size as the pediatric otoscope (Welch Allen) tip. During an otoscopic exam, debris frequently

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adhered to the otoscope and the procedure itself was noted to re-expand a collapsed external ear canal. Therefore, the purpose of this study was to evaluate the effects of two simple ear canal cleaning procedures on improving emissions. A secondary purpose was to confirm that the research procedures could easily be carried out by screening technicians and therefore are viable in a clinical setting. The first procedure consisted of inserting an otoscope to view and dilate the ear canal and removing any attached debris prior to repeating the test; the alternate procedure consisted of inserting the ILO88 ear probe, running a test, removing the probe, removing any debris adhering to the probe, and refitting the probe without viewing the ear canal prior to repeating the test. The hypothesis was that both of these simple interventions to dilate the ear canal and remove superficial debris would improve the emission response.

METHOD

The study data were derived from full-term, normal nursery infants who were presented for routine neonatal screening between March 19, 1993 and February 12, 1994. Infants were randomly enrolled into either the otoscopic or refit protocol until all six study groups contained at least 50 ears. Robust emission study groups were completed first because of the high overall pass rate of the screen program. Mean age at testing for study infants was 23 ± 7 hours for the otoscopic group and 22 ± 8 hours for the refit group. Three hundred and sixteen ears were studied with an initial TEOAE followed by either the otoscopic fit procedure or the refit procedure. At least 50 ears with an initial robust emission, 50 with an initial weak emission, and 50 with no emission were studied for both the probe fit procedure and the otoscopic viewing procedure. The TEOAE robust emission group was included as a control and to substantiate that there are no negative effects derived from the probe refit or otoscopic view procedure. Table 1 shows the study sample, which consisted of a total of 316 ears: 159 were in the otoscopic view protocol and 157 ears were in the refit protocol. Robust emission (a standard pass) was defined as an emission with at least a 3-dB signal-to-noise ratio between 1 and 2 kHz, 2 and 3 kHz, and 3 and 4 kHz. A weak emission (a standard refer) was defined as having an emission present within at least one frequency band but not all three, and no emission (a standard refer) was defined as having no emission present in any of the three frequency bands.

Table 1 Study Sample

Initial TEOAE Emission	*Otoscopic View Procedure*	*Refit Procedure*
	Ears	*Ears*
Robust	55	50
Weak	51	50
None	53	57
Total	159	157

OAE Procedure

All procedures were completed by one of two screening technicians with 3 years of TEOAE testing experience. In addition, they had been trained to reliability in the otoscopic exam procedures by a physician (Dr. Betty Vohr). The infant was brought to the screening room routinely used for newborn screening (ambient noise = 60 dBA SPL). The infant was positioned in an Armstrong incubator (model 500, Ohio Medical Products, Madison, Wisconsin) with an ambient noise level of 45 dBA SPL. The Otodynamic Analyzer, ILO88, was used to record click-evoked OAEs from each ear with a standardized procedure. Noise level (dB SPL), stimulus level (dB), emission response (dB SPL), and robust emission, weak emission, and no emission status were recorded.

Experimental Procedure 1: Otoscopic Exam

The pediatric probe used with the ILO88, with an appropriate-sized rubber tip, was introduced into the ear canal and a snug fit was obtained. Probe fit was determined by obtaining an adequate stimulus across the 0.5- to 5-kHz frequency range and setting the stimulus to obtain an approximate sound pressure level of 84 dB. At least 60 emission samples, but not more than 260 (low noise), were collected. After the first test was run, the probe was removed and the ear canal was viewed with a Welch Allen pediatric otoscope. The status of the ear canal was coded as either (1) no obstruction (no debris), (2) partial obstruction (small to large debris present, but at least part of tympanic membrane visualized), or (3) total obstruction (filled with debris, no part of tympanic membrane visualized). Likewise, collapse of the ear canal was recorded. After the otoscopic viewing,

the probe tip was cleaned of any attached debris, reinserted, and the second TEOAE was run with identical procedures.

Experimental Procedure 2: Probe Refit

The initial part of Procedure 2 was similar to Procedure 1, with a probe fit obtained and running of the first TEOAE test. After completion of the test, the probe was removed, any debris attached to the probe was removed, and the second TEOAE test was repeated with identical procedures.

Additional Procedures

If an ear did not demonstrate a pass after the research protocol and experimental procedures were completed, the screener performed one or more of the following procedures, based on clinical judgment and our previous experience. (See Vohr et al, 1993, for a discussion of these issues.) Additional procedures were recorded and included the following:

1. Changing the tip size to achieve a better fit—two sizes, for smaller and larger neonates;
2. Increasing the number of runs;
3. Turning the infant over to drain debris;
4. Increasing the stimulus to a maximum of 90 dB;
5. Repeating the otoscopic exam;
6. Repeating the test the next day; and
7. A combination of the above procedures.

Statistical analyses included repeated measures (pre- and post-exam procedure) analysis of variance (ANOVA) with appropriate post hoc tests for the continuous variables and chi-square analysis for categorical variables.

RESULTS

Changes in test emission status after the otoscopic and refit procedures are shown in Table 2. Improvements occurred for the otoscopic procedure with 12 of 51 (24%) weak emissions converted to robust emissions, 10 of 53 (19%) no emissions converted to robust emissions, and 15 of 53 (28%) no emissions improved to weak emissions. In the refit group, 20 of 50 (40%) weak emissions converted to robust emissions, 13 of 57 (23%) no emissions converted to robust emissions, and 9 of 57 no emissions (16%) improved to weak emissions. One ear in the refit group converted from a robust to a weak emission.

Table 2 Comparison of Screen Results of First and Second TEOAE Procedures

Emission Groups	First TEOAE n	Second TEOAE Robust (%)	Second TEOAE Weak (%)	Second TEOAE None (%)	p
Otoscopic Protocol					
Robust	55	55 (100)	0	0	<.0001
Weak	51	12 (24)	36 (71)	3 (5)	
None	53	10 (19)	15 (28)	28 (53)	$x^2 = 133.5$
Refit Protocol					
Robust	50	49 (98)	1 (2)	0	<.0001
Weak	50	20 (40)	28 (56)	2 (4)	
None	57	13 (23)	9 (16)	35 (61)	$x^2 = 118.2$

Average stimulus for all tests was 85.9 dB and mean noise level was 35.4 dB SPL. TEOAE responses for all ears in dB SPL are shown in Table 3. There was a significant improvement in emission response with both procedures for all ears including robust, weak, and no emission groups.

Table 4 shows the amount of debris or canal collapse observed by the technician during otoscopic examination. Seventeen of 159 (10%) canals were observed to be completely obstructed. The increased amount of debris was significantly related to decreased emission ($x^2 = 24$, $p < .0001$). Although there was a relationship between increasing incidence of canal collapse and decreased emission, it did not reach

Table 3 TEOAE Response in dB SPL

	n	Otoscopic Pre	Otoscopic Post	df	F	p
Robust	55	19.6 ± 4	20.1 ± 4	1	16.2	0.0002
Weak	51	5.0 ± 5	6.9 ± 5	1	16.8	0.0001
Weak*	12	5.9 ± 4	8.8 ± 3	1	5.7	0.035
None	53	0.2 ± 1	5.7 ± 8	1	24.6	0.0001
None*	10	0.78 ± 3	20.2 ± 2	1	289.8	0.0001
		TEOAE Refit				
	n	Pre	Post	df	F	p
Robust	50	19.9 ± 5	20.6 ± 5	1	10.2	0.0025
Weak	50	7.2 ± 6	9.7 ± 7	1	18.3	0.0001
Weak*	21	9.48 ± 5	14.5 ± 5	1	31.6	0.0001
None	57	0.4 ± 2	3.8 ± 7	1	17	0.0001
None*	13	1.2 ± 3	14.5 ± 4	1	87.5	0.0001

$p < .01$.
*Subgroup that improved to pass category after procedure.

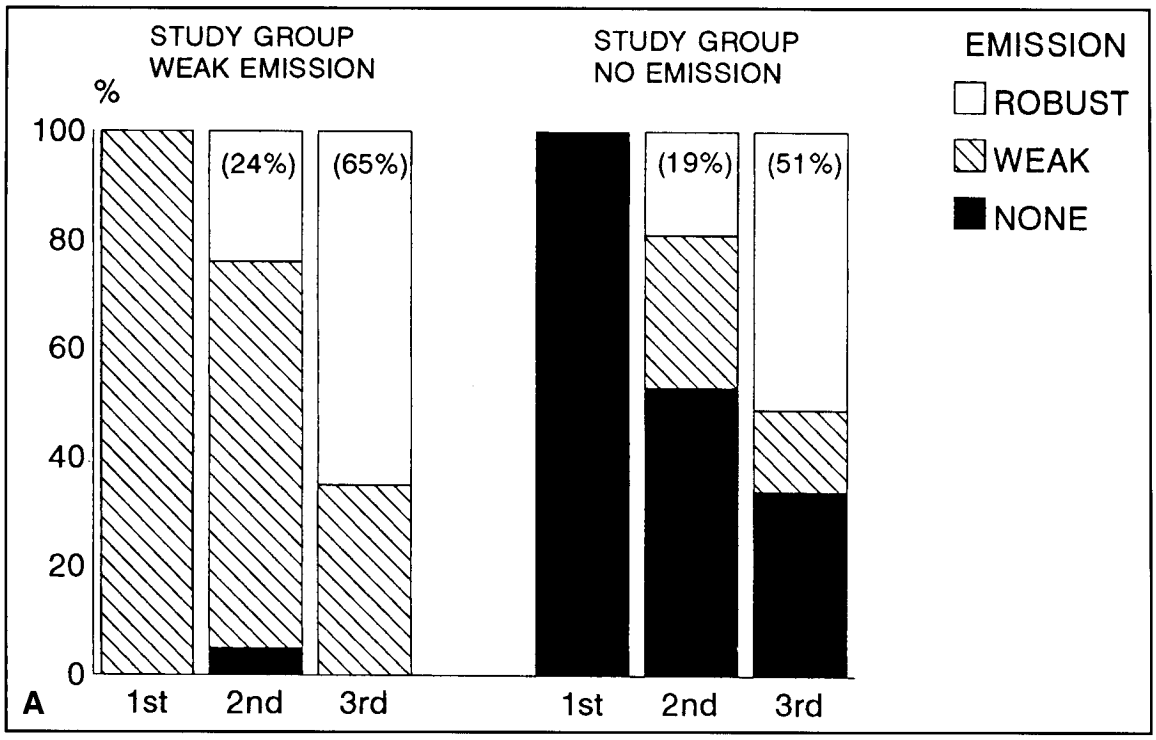

Figure 1A The bar graph depicts the results of the first, second, and third TEOAE for the weak and no emission ears in the otoscopic protocol.

statistical significance ($x^2 = 5.9$, $p = .051$). Thirteen percent of robust emissions, 16 percent of weak emissions, and 30 percent of no emissions had evidence of canal collapse. Forty of 51 (78%) weak emissions and 44 of 53 (83%) strong emissions had either debris or collapse.

After the formal research protocol was completed, a further attempt was made to change the result to a robust emission, if time permitted, by initiating one or more additional procedures.

Table 4 Relationship Between External Ear Canal Findings and Initial TEOAE Result in the Otoscopic Group

Emission	*None (%)*	*Partial (%)*	*Complete (%)*	x^2
Obstruction of Ear Canal				
Robust	37 (51)	18 (26)	0	
Weak	16 (22)	28 (42)	7 (36)	$x^2 = 24$
None	20 (27)	21 (31)	12 (63)	.0001
Emission	*Yes*	*No*		x^2
Collapse of Canal				
Robust	7 (13)	48 (87)		
Weak	8 (16)	43 (84)		$x^2 = 5.9$
None	16 (30)	37 (70)		.051

Table 5 shows the data on ears with a weak or no emission response on which an additional procedure was attempted. The most commonly utilized procedure was tip change, which resulted in converting the emission to a robust emission (pass) in 16 of 17 (94%) of ears. Initial, second, and final TEOAE emissions status for all ears with initial weak emission and no emission TEOAE within the two study protocol groups are shown in Figure 1. TEOAE results improved significantly with additional procedures for both weak emission and no emission groups ($p < .0001$). Weak emissions converted to robust

Table 5 Results of Additional Clinical Procedures

Procedure	*n*	*Successful Conversion to Pass (%)*
Change tip	17	16/17 (94)
Increase number of runs	9	6/9 (67)
Turn baby over	2	2/2 (100)
Increase stimulus	2	2/2 (100)
Repeat otoscopic	7	7/7 (100)
Repeat next day	2	2/2 (100)
Change tip plus otoscopic	2	1/2 (50)
No additional procedure completed		

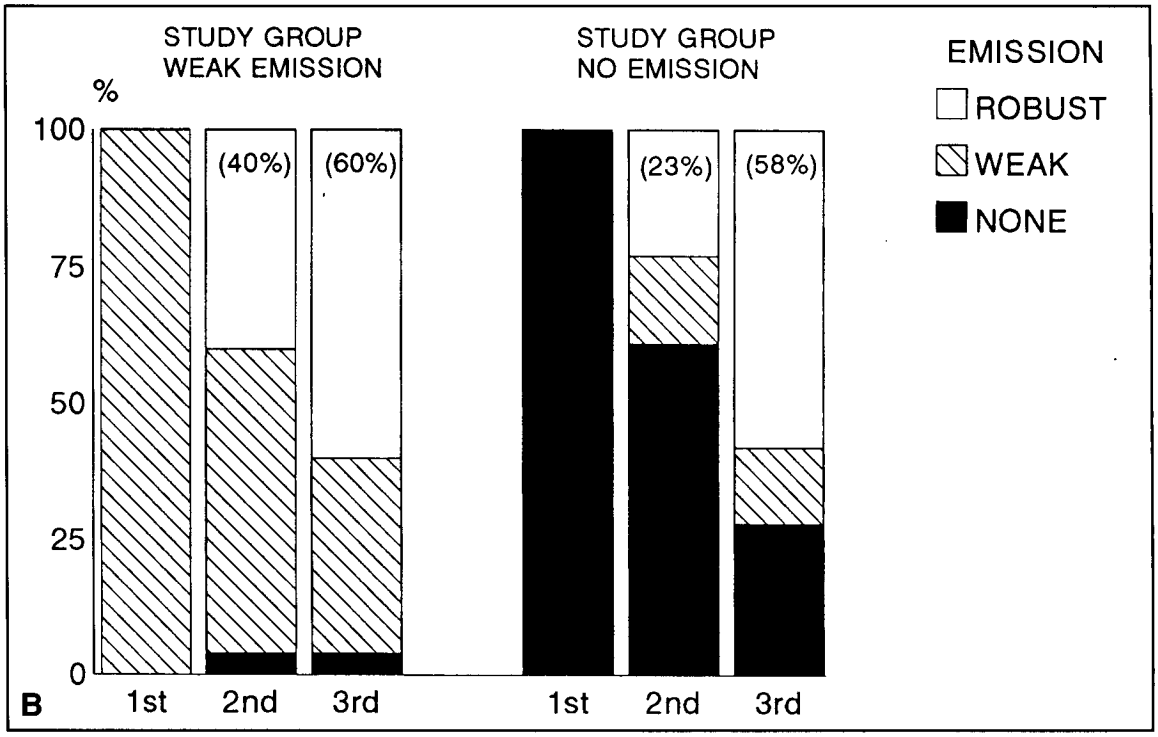

Figure 1B The bar graph depicts the results of the first, second, and third TEOAE for the weak and no emission ears in the refit protocol.

emissions in an additional 31 ears. This resulted in a final robust emission in 63 of 101 (62%) ears in the initial weak emission group (refit plus otoscopic) and 60 of 110 (55%) ears in the initial no emission group (refit plus otoscopic).

DISCUSSION

The TEOAE test response expressed both in dB SPL and categorically as no emission, weak emission, and robust emission improved significantly for both the otoscopic viewing group and the refit group after the two study procedures, supporting our hypothesis. Improvement in emissions and pass rates post procedure were similar for the two procedures, suggesting that an otoscopic viewing provides no additional benefit and that the simpler probe cleaning with refit is effective. This finding is important, since a refit procedure can be easily implemented by a trained paraprofessional.

In fact, the results of the otoscopic viewing revealed that there were no initial passes among ears with complete obstruction, supporting the important role of debris on test results in neonates. The finding of an increased amount of debris in the ear canal and a trend for an increase of canal collapse in infants who fail the TEOAE is consistent with our previous findings (Chang et al, 1992) and supports the importance of a procedure to remove debris. Data from the otoscopic protocol suggest that occasionally debris may, in fact, be dislodged and convert the ear from a robust or weak emission to no emission. Our previous study demonstrated improved TEOAE results after cleaning of debris from the ear canal under direct vision using a pediatric Calgis swab (Chang et al, 1992). In addition, the collapsed canal was insufflated with a pneumatic bulb to help expand the canal. These two more complex procedures were not completed in this cohort and observations of the status of the tympanic membrane were not recorded. Middle ear effusion in the neonate is, however, a rare phenomenon (Keith, 1975; Cavanaugh, 1987) and, as such, was not considered an important determinant of TEOAE results. These data do, however, indicate that a simple probe cleaning procedure can be effective in improving the TEOAE response.

Finally, the improved results achieved after the additional procedures were completed strongly suggest that an optimal pass may not be achieved after a single procedure but may require two or more procedures, depending upon infant, environment, and test conditions. We

conclude that the refinement of testing procedures continues to improve the specificity of the TEOAE neonatal screen. Either a simple refit procedure or an otoscopic viewing with removal of any attached debris and expansion of a collapsed canal will increase the recording of emissions. Additional easily implemented procedures may increase test time but will also further improve the pass rates.

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