*Acta oto-rhino-laryngologica belg.*, 1996, **50**, 203-209

# Neonatal hearing screening with otoacoustic emissions : an evaluation

*K. Daemers, J. Dirckx, K. Van Driessche, Th. Somers, F. E. Offeciers and P. J. Govaerts*

E.N.T. Department, Sint-Augustinus Medical Institute (U.I.A.), Antwerp, Belgium

**Key words.** Neonatal hearing screening ; otoacoustic emissions

**Abstract.** *Neonatal hearing screening with otoacoustic emissions : an evaluation.* For several years now, it is possible to test the cochlear function immediately after birth in an easy way by means of click evoked otoacoustic emissions. Thanks to this early detection, hearing aid fitting and appropriate hearing rehabilitation can now be started at a very young age, which significantly enhances the possibility of integration of the congenitally hard of hearing in society. An international consensus is growing to endorse a universal neonatal hearing screening in western societies. Setting up screening programs necessitates good preparation, continuous quality control and regular analysis of procedures and results. The present paper evaluates the procedure as organised from January 1993 till December 1994 in the University ENT-Department of the Sint-Augustinus Hospital. Of the 907 included neonates who were considered not to be at risk for hearing loss, 81% passed the test immediately, and 93% passed after maximum 3 tests. Some changes in the initial procedure increased the prevalence of emissions from 69% to 84%. The practical problems of the screening program and especially the importance of a stringent follow-up procedure in case of failure, are discussed.

## Introduction

Epidemiological studies teach us that the incidence of congenital bilateral neurosensory deafness in Western countries can be placed between 1/1000 and 1/2000. Less acute hearing loss undoubtedly occurs more at the rate of 1.5 to 6 neonates per 1000 (1, 2, 5). The effect of such disorders on the speech and language development of the child and on the social and professional situation is important. Because of auditory deprivation, learning processes become severely hampered. The influence is not only evident in the learning of speech and language. Because written and spoken language are the most important means in our society for the transfer of knowledge, hearing loss also influences the social, emotional and cognitive development. Detection, equipment and follow-up before the age of 6 months, are essential to obtain optimum development (3).

For the moment, screening in Belgium is carried out by means of the Ewing test, which is performed at the age of about 9 months by the Well Baby Clinics. This form of screening has been applied since 1976 and has the great distinction of having made possible the first structured detection. The greatest disadvantage is the lateness in terms of equipment. Another problem is the relatively limited epidemiological coverage ; only 78% of the fractionalised number of births was screened in 1993. This, however, is not a problem typically related to Ewing, rather a problem of every screening examination which is not carried out during maternity. The problem of follow-up is similar in nature ; parents are encouraged to repeat the Ewing test or to investigate further, but they do not always respond to this or possibly do not inform the Well Baby Clinic of the results. Therefore follow-up is lacking in 30% of children who failed a maximum of 3 Ewing tests during the year 1993. In this sense, it is very difficult to draw conclusions about the sensitivity of the Ewing test as it is currently organised.

If the Ewing test is aimed at all children with impaired hearing (hearing loss of more than 30 dB) including transmission disorders, then specificity amounts to an estimated 96%. If, however, the intention is to track only perceptively hard-of-hearing children, then an estimated specificity of 88% is reached. These figures are estimated on the basis of the population of children followed-up after a failed Ewing test. This concerns the specificity after 2 or 3 tests. The pass percentage after the first test amounts to 76% (Kind en Gezin Antwerp, personal communication).

The first apparatus for the measurement of otoacoustic emissions became available in 1986. Otoacoustic emissions are sound waves which are generated in the cochlea as a consequence of its nonlinear characteristics. They are almost certainly caused by the functioning of the outer hair cells which possess contractile characteristics. An incoming soundwave causes contractions of these cells, causing amplification of the soundwaves over a very limited area of the basilar membrane and thereby ensures "tuning" in the frequency area. A secondary characteristic of this function is the creation of a vibration wave in the cochlea, which in an inverse way via the middle-ear, reaches the outside world where it can be detected. This recurring wave is known as otoacoustic emission (OAE) and it provides evidence of perfectly functioning outer hair cells and, of course, evidence of a perfectly conductive inner ear.

Because the outer hair cells are the first to be affected by most hearing disorders, the detection of the otoacoustic emission at the same time is useful as a hearing evaluation. Major research has demonstrated that the presence of OAE's indicates hearing with levels better than about 30dB at the best frequency. In the case of a transmission loss greater than 30dB be it sensorineural or conductive, emissions are absent (5, 6).

Because of the relative simplicity and speed of tests, OAE's are currently being introduced as screening instruments for hearing problems. The fact that they can already be taken at neonatal age, provides an extra advantage in the field of early diagnosis and therapy. A lot more research is still necessary to evaluate the merits of OAE's as screening instruments.

A screening programme was started in the Sint Augustinus medical institute in 1993. This paper reports the measured results of the screening, utilising click evoked otoacoustic emissions taken from regularly born neonates over a period of 2 years. The practical problems associated with the set-up of a screening experiment are discussed.

## Material and method

During 1993 and 1994, 907 regularly born neonates were tested by the University ENT department of the Sint-Augustinus Medical Institute by means of an examination using non-linear click evoked OAE's. All examinations were made using the Otodynamics IL088 apparatus. The Quick Screen Test was utilised.

The test was completed following the method of Kemp and Bray, whereby a neonatal probe with a rubber cap was inserted into the auditory channel and then the stimulus controlled and adjusted (4). The stimulus level reached a maximum of 90 dBSPL. The probe is positioned in such a way that the click does not cause any resonance in the auditory channel (see figure 1 window "stimulus") and the frequency spectrum is as flat as possible (see figure 1 window "power analysis stimulus").

A minimum of 20 and maximum of 260 readings were taken. The examination was stopped when emissions were present. If, after 50 readings there was insufficient response (see below), then an immediate change was made to a new check-fitting with repeated tests. Under favourable circumstances the registration lasted less than one minute per ear, but

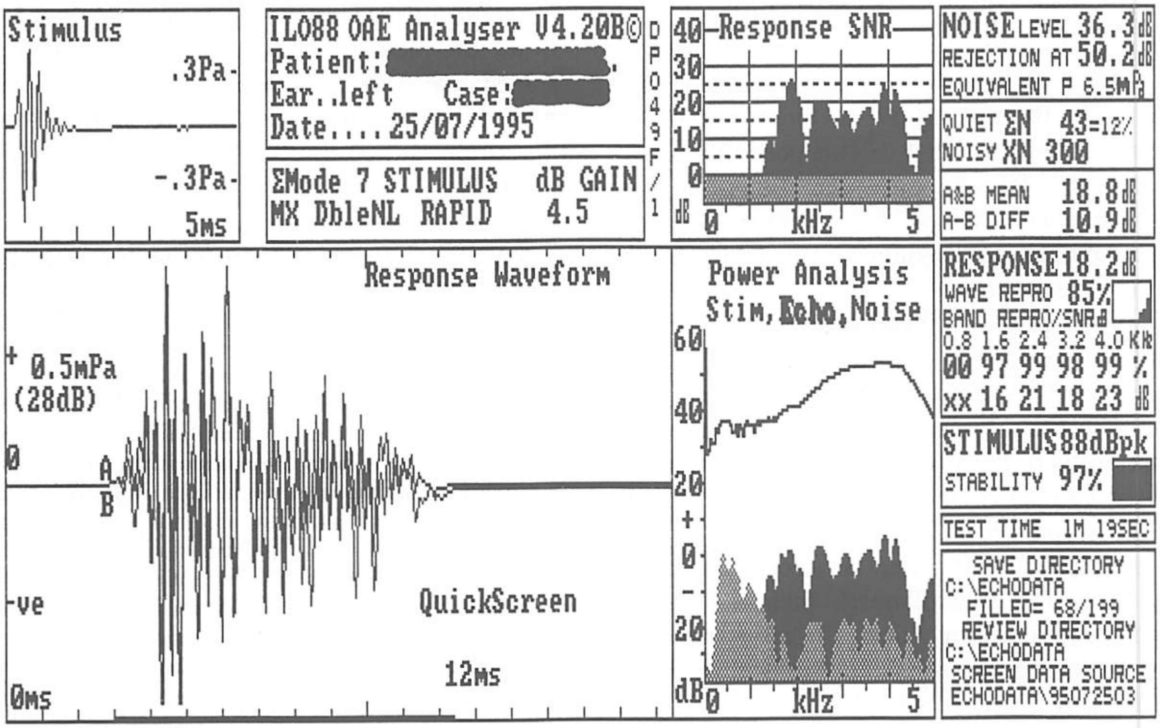


*Fig. 1*

Print-out of the computer screen of the ILO 88. In the window "stimulus" we observe a representation of the sound measured by the microphone of the probe. The window "power analysis stimulus" shows the frequency spectrum of the stimulus. Below this the response is depicted. In this window we can see by how many dB the stimulus exceeds the noise level (S/R ratio) for each frequency band, with centre frequencies 0.8, 1.6, 2.4, 3.2 and 4.0 kHz (stimulus = black ; noise level = grey).

could, in exceptional cases, last longer than a quarter of an hour.

The neonates were tested in a sound-proof cabin or a quiet room at the Audiological Centre of the University ENT department. The neonates were mostly brought to the test location by their mothers, about one and a half hours after feeding.

The opportunity to apply for an examination by otoacoustic emissions was given to the parents of every new-born child by means of a letter, which gave a brief explanation and included a simple registration slip. Newly-born children admitted to neonatology were systematically tested but, because they form another target group, they were not taken into consideration for the purpose of this paper.

From January until April 1993 the examination took place immediately after registration. From May 1993 emissions were systematically tested on the last working day before leaving hospital. This means that, at the earliest, the neonates were tested at the age of three days. This change in the procedure was important. In the rest of the report reference will be made to periods 1 and 2.

Until the end of 1993 the presence of emissions was assessed on the basis of a qualitative evaluation from the Fourier spectrum. A criterion was established that for frequencies between 1 and 4 kHz the average emission response had to significantly exceed the noise level. From February 1994 onwards, the new software (version 3.94) was at our disposal. With this, the signal to noise ratio (S/R ratio) in different frequency bands can be determined and thus the application of a numeric criterion became possible. We concluded that OAE's were present if in the case of the three frequency bands with centre frequencies 2.4 kHz, 3.2 kHz and 4 kHz, the S/R ratio exceeded 6 dB. Because in the frequency band with a centre frequency of 1.6 kHz it is difficult to achieve sufficient stimulus, the criterion for these frequencies is established at an S/R ratio of 3 dB. By making use of these criteria, the general performance levels are generally greater than 50%. In cases of doubt, the visual score was applied whereby the examiner falls back on the qualitative assessment provided by the Fourier spectrum.

In the case of unilateral or bilateral failure, immediately following the test the parents were orally invited to a repeat examination 3 weeks later. If after 6 weeks no repeat examination had been planned, then the parents were contacted once or twice in writing. In the last quarter of 1994, the follow-up strategy was changed. If after 4 weeks no repeat examination was planned, then the parents were contacted in writing. If after this there was no reaction, then the family doctor was informed of the hearing test failure. If necessary, the parents and the family doctor would again be contacted in writing.

## Analysis of results

Of the 907 neonates 13% (118) unilaterally failed the first test. The percentage of bilateral failures at the first test amounted to 6% (53). During the first test, we found OAE's present in 81% (736) of the tested neonates.

After an initial test period of 4 months, an intermediate analysis of the results was carried out.

In both the first and second periods, 19% of the neonates were presented for examination (151/798 and 756/3979 respectively). By means of an intermediate evaluation, the above mentioned procedural change was effected. The percentage of unilateral failures in the first period amounted to 22.5% and in the second to 11%, and the percentage of bilateral failures dropped from 8.5% to 5.3%. Thus, the prevalence where emissions were present increased from 69% to 83.7%.

Table 1 summarises the results of the screening.

Follow-up of the failures is shown in figure 2. From the 118 unilateral failures, 88 neonates were tested a second time. The other 30 received no second examination, notwithstanding the fact that their parents were invited several times to repeat the test. From the 88 retested neonates, 73 showed normal emissions and in 15 cases emissions remained unilaterally absent. From these 15 failures, 7 neonates were examined a third time, 8 were not. From the 7 neonates receiving the third examination, there were 6 where OAE's were present.

There were 53 bilateral failures. Of these, 40 neonates were retested and 13 not. The parents of the latter group of neonates also received repeated invitations for retesting. Of the 40 retested neonates, 23 showed bilateral emissions, 5 only unilateral and 12 where emissions were again absent on both sides. Two neonates with unilateral failures were retested a second time with success, but three received no second retest. Only 4 of the bilateral failures at the retest received a second retest and in 3 cases otoacoustic emissions appeared to be present. The neonate with

*Table 1*

The screening results of the first test of 907 neonates tested in 1993 and 1994
The absolute totals are between brackets

| | 1/1/1993 to 30/4/1993 n = 151 | 1/5/1993 to 31/12/1994 n = 756 | Total n = 907 |
|---|---|---|---|
| OAE present | 69% (104) | 83,7% (632) | 81% (736) |
| OAE bilaterally absent | 8,5% (13) | 5,3% (40) | 6% (53) |
| OAE unilaterally absent | 22,5% (34) | 11% (84) | 13% (118) |

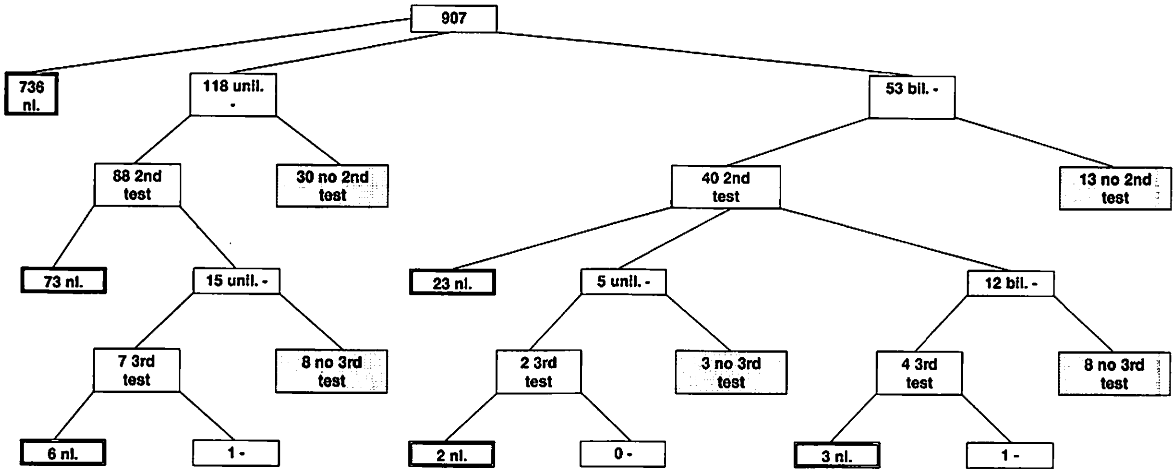


*Fig. 2*

Results of the first OAE examination and of the follow-up examinations of failures. viz : presence of OAE's, unil- : unilateral absence of OAE's, bil- : bilateral absence of OAE's. The shaded blocks indicate possible problem cases which were lost to further follow-up. A double frame indicates the final presence of OAE's and thus indicates normal hearing.

persistent bilateral emission failure was followed-up : it was a case of persistent glue. After the placing of diabolos a BERA was carried out, which showed normal levels.

The number of failures at the first test amounted to 171. This includes 118 unilateral and 53 bilateral failures. Of the 118 unilateral failures, 32.2% received no follow-up (4.2% of the total population of 907 neonates). Of the 53 bilateral failures, the number of neonates without follow-up was much higher, i.e. 45.3% (2.6% of the total population).

We must mention that three of those neonates who bilaterally failed the first test, failed unilaterally at the second test. This brings the actual percentage of bilateral failures without follow-up after the first or second failure to 39.6% (2.3% of the total population), and the percentage of unilateal failures without follow-up after the first or second failure to 34.7% (4.5% of the tested population).

Of the 907 neonates, 6.8% received no complete follow-up after failure in the first or second OAE examination.

Finally, this means that, after 2 or 3 tests, OAE's were present in 93% of the tested population.

Table 2 summarises the results after a maximum of 3 tests.

## Discussion

About 2400 children are born annually in the Sint-Augustinus Medical Institute. Since 1993, the parents have been given the chance to have the hearing of their neonates tested. Since 1994 this has taken place systematically for children attending the neonatology department and whom we consider to be "children at risk". This group is not taken into consideration in the present report. Our population is not therefore representative of the total population of newly born infants. For this reason the incidence of hearing problems referred to in this report, is possibly lower than the incidence in the total neonatal population.

After childbirth, mother and child generally remain in hospital for about five days. In the first phase of our project, a hearing examination was arbitrarily planned during that week. Because there were indications that OAE's could probably only be detected a few days after the birth (7), hearing examinations in the second phase of the project were planned on the last working day of the hospitalisation period. Moreover, the interpretation of the results became more certain, thanks to the new software described in "Material and Method". These modifications, together with the

*Table 2*

The screening results after a maximum of 3 tests of 907 neonates in 1993 and 1994 as a function of the result of the first test.
The figures are percentages within each group (= row).
The numbers in brackets are the percentages within the total population (n = 907)
— stands for absent OAE's

| result 1st test | normal after max. 3 tests | failure after 2 or 3 tests | no follow-up |
|---|---|---|---|
| unilateral n = 118 | 67 (8,7) | 0,8 (0,1) | 32,2 (4,2) |
| bilateral n = 53 | 52,8 (3) | 1,9 (0,1) | 45,3 (2,6) |
| normal n = 736 | 100 (81,3) | | |
| total | 93 | 0,2 | 6,8 |

increased experience of the examiners, have led to an increase of detected OAE's from 69% to 84%.

In comparison with other authors this prevalence is rather low ; we found higher prevalence figures in the literature. For example, Kok, among others, found a 99% prevalence of emissions present in neonates older than 108 hours (7). Many authors, however, give little information on the composition of the experimental group. It is not unlikely that for some experiments the measurements were taken only in cases of easy probe placement.

Clinical practice teaches us that OAE's often appear to be measurable from neonates after repeated attempts to place the probe.

Prevalence figures are presumed to be influenced to a large degree by factors such as the size and curvature of the auditory channel. The system IL088 only provides information concerning the stability of the probe. Information regarding the positioning of the probe in relation to the wall of the auditory channel cannot be obtained. These technical problems also have repercussions on the achievable prevalence figures. Other research groups have also encountered these problems (Morlet, Collet, personal communication). It is therefore possible that development in the area of probe design and feedback about probe placement can make higher prevalence numbers attainable.

Within the present structure the follow-up of failures was a major problem. During the first test there were 171 failed neonates, of whom 32.2% of the unilateral failures and 45.3% of the bilateral failures could not be followed-up any further (see table 2). Considerable effort was made to encourage the parents to offer their children a further follow-up. The biggest problem was, and is, the achievement of the follow-up, upon which the value of a screening programme stands or falls. A completely reliable hearing screening can only be achieved through a major committment from all the doctors who come in contact with the child. A general policy for the detection of hearing problems is necessary.

Examination of the OAE's gives a better pass percentage after the first test than the Ewing test, viz. 81% compared with 76%. When, with the hearing test we aim at the perceptive hearing disorders, we see that examination by OAE's is 5% more specific than with Ewing. After 2 or 3 tests the specificity of the Ewing amounts to 88%, whereas the specificity of the examination by OAE's amounts to 93% after a maximum of 3 tests. If it is the intention to detect all hearing problems, including the middle ear disorders, then the Ewing appears to be more specific (96% compared to 93%).

The most important advantage of examination by otoacoustic emissions is undoubtedly the timing. Various authors have already stressed the importance of early detection (3).

Utilization of OAE's makes it possible to test neonates in a non-radical, simple and reliable way, so that the treatment of children with hearing disorders can start between the ages of 3 and 6 months. It is clear that the impact of the hearing problem can be reduced by dealing with it at an early stage and a child with hearing disorders has, in that case, a much greater chance of integrating into society. In some states of the USA the right to undergo a hearing screening is established by law. In our present study of 907 neonates, there were no bilaterally handicapped hard of hearing, but since then, some have already been detected and helped by fitting hearing aids and providing treatment before the age of 6 months.

The development of hearing apparatus as well as traditional apparatus such as the Cochlear implant is evolving rapidly. Early stimulation of the hearing nerves so as to obtain an optimal organisation in the auditive cerebral cortex, is of the utmost importance.

Whether hearing screening of all neonates is justified is a good question. Although this is a political and not a medical question, we would like nevertheless to raise one or two points which may generate discussion on the subject. Medical science utilises all the means at its disposal to give the maximum opportunity of social integration to the hard of hearing. This objective has still not yet been achieved. The hard of hearing still face enormous difficulties to integrate socially and to avoid being relegated to the "alternative" social group of the "deaf and hard of hearing", where although they are surrounded by well-intentioned care, they become isolated from society with good hearing. Fortunately, science is making great progress, both in the diagnostic field (e.g. genetic examination of deafness), and in the therapeutic field (e.g. Cochlear implantation). Early detection leads to early therapy and we are becoming more and more aware that the earlier the therapy, the greater the chance of social integration. In Belgium there are still too many children in whom congenital hearing loss is only detected at the age of 2 or 3 years. In the present state of science and social welfare, this can no longer be morally justified.

## Acknowledgements

The authors wish to thank the pediatricians and nursing staff of the pediatric and neonatology departments of the Sint-Augustinus hospital for their very willing cooperation and also R. Windmolders, E. Desaeger and H. Stuelens for the extensive fieldwork that they carried out within the structure of their dissertations to the Logopedic and Audiology department of the Katholieke Vlaamse Hogeschool of Antwerp.

## References

1. Wadkin P., Baldwin M., McEnery G. Neonatal at risk screening and the identification of deafness. *Archives of diseases in childhood*, **66**: 1130-1135, 1991.
2. White K., Vohr B., Behrens Th. Universal Newborn Hearing Screening Using Transient Evoked Otoacoustic Emissions : Results of the Rhode Island Hearing Assessment Project. *Seminars in Hearing*, **1** : 18-29, 1993.
3. Kuhl P., Williams K., Lacerda F., Stephens K., Lindbloom B. Linguistic experience alters phonetic perception in infants by six months of age. *Science*, **255** : 606-608, 1992.
4. Bray P., Kemp D. An advanced cochlear echo technique suitable for infant screening. *British Journal of Audiology*, **21** : 191-204, 1987.
5. Vohr B., White K., Maxon A. B., Johnson M. J. Factors Affecting the Interpretation of Transient Evoked Otoacoustic Emission Results in Neonatal Hearing Screening. *Seminars in Hearing*, **1** : 57-72, 1993.
6. Kemp D., Ryan S., Bray P. A Guide to the Effective Use of Otoacoustic Emissions. *Ear and Hearing*, **2** : 93-105, 1990.
7. Kok M., Van Zanten G., Brocaar M., Wallenburg H. Click-Evoked Oto-Acoustic Emissions in 1036 Ears of Healthy Newborns. *Audiology*, **32** ; 213-224, 1993.

P. J. Govaerts
University E.N.T. Department
Sint-Augustinus Medical Institute
Oosterveldlaan 24
2610 Wilrijk, Belgium