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MAIN ARTICLE

The use of transient evoked otoacoustic emissions as a hearing screen following grommet insertion

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Abstract

Objective: This study aimed to evaluate the sensitivity of transient evoked otoacoustic emission testing as a screening tool for hearing loss in children, after grommet insertion.

Method: A prospective study was conducted of 48 children (91 ears) aged three to 16 years who had undergone grommet insertion for glue ear. At post-operative review, pure tone audiometry was performed followed by transient evoked otoacoustic emission testing. Outcomes for both tests, in each ear, were compared.

Results: The pure tone audiometry threshold was ≤20 dB in 85 ears (93.4 per cent), 25 dB in two ears (2.2 per cent) and ≥30 dB in four ears (4.4 per cent). Transient evoked otoacoustic emissions were detected in 69 ears (75.8 per cent). The sensitivity of transient evoked otoacoustic emission testing for detecting hearing loss was 100 per cent for ≥30 dB loss but only 66.7 per cent for ≥25 dB loss.

Conclusion: Transient evoked otoacoustic emission testing offers a sensitive means of detecting hearing loss of ≥30 dB following grommet insertion in children. However, the use of such testing as a screening tool may miss some cases of mild hearing loss.

Key words: Otoacoustic Emissions; Otitis Media With Effusion; Middle Ear Ventilation

Introduction

Pure tone audiometry (PTA) is routinely used in the post-operative assessment of children undergoing grommet insertion in the UK. The purpose of such hearing screening is threefold. Firstly, post-operative documentation of normal hearing thresholds allows post-insertion hearing improvement to be quantified. Secondly, PTA helps to identify persistent middle-ear disease, which may be missed if patients are screened with otoscopy alone. Finally, sensorineural loss resulting from grommet insertion has been recorded, although rarely, and its identification is important for clinical as well as medicolegal reasons.

However, the use of PTA as a hearing screen following grommet insertion does have some drawbacks. The large number of patients undergoing grommet insertion would represent a heavy workload for audiology departments. Furthermore, patients are often young and uncooperative with hearing assessment, making it a potentially time-consuming process.

Otoacoustic emission (OAE) testing is a simple method which provides a 'pass or fail' assessment of hearing. Such testing offers a fast, non-invasive means of hearing assessment, and has been used nationally in the UK National Health Service neonatal hearing screening programme since 2006. Otoacoustic emission testing is also used to evaluate the hearing of patients with learning difficulties, and to identify non-organic hearing loss.

There are four major subtypes of OAE. This study focussed on the use of transient evoked OAEs (TEOAEs), which are generated by the outer hair cells of the cochlea in response to brief acoustic stimuli.[1,2] They are present in 98 per cent of normal ears, but are diminished or absent in ears with hearing loss or immediately following surgery.[1,3–6]

This study aimed (1) to evaluate the diagnostic accuracy of TEOAE testing for detecting hearing loss following grommet insertion, and (2) to thus determine the efficacy of such testing as a hearing screen in this context.

Materials and methods

Study design and population

A prospective study was conducted in a large district general hospital.

The study population comprised patients aged zero to 16 years who had undergone grommet insertion

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for otitis media with effusion (OME) between August 2008 and June 2009. All patients had audiometric and/or tympanometric evidence of OME pre-operatively.

Grommet insertion was performed using either Shah grommets or collar button tubes.

Patients were recruited into the study at their routine follow-up appointment, by the lead author OD. Only patients who were reviewed a minimum of 40 days post-operatively, and who were compliant with PTA and transient evoked OAE (TEOAE) testing, were included in the study. Patients who underwent grommet insertion for reasons other than OME, and patients who had received concomitant mastoid surgery, were excluded from the study.

Ethical approval for the study was obtained from the local research ethics committee. Informed consent for the additional tests was obtained from patients and parents prior to testing.

Outcome

All patients underwent otoscopy, followed by PTA and TEOAE testing.

All hearing assessments were performed by a senior audiologist in an acoustically treated room (with ambient noise levels of less than 30 dBA and a reverberation time of less than 0.25 seconds). Pure tone audiometry was performed at frequencies of 0.5, 1, 2 and 4 kHz. Pure tone thresholds were considered to be 25 dB when air or bone thresholds were 25 dB at two or more tested frequencies on PTA. Pure tone thresholds were considered to be 30 dB when air or bone thresholds were 30 dB at two or more tested frequencies on PTA. Bone conduction thresholds were not routinely tested unless air conduction thresholds exceeded 20 dB.

Otoacoustic emissions were recorded using an Otodynamics Echocheck ILO-88 OAE screener (Otodynamics, Hatfield, UK), using the 'quickscreen' option, in non-linear mode. This screener used a click stimulus over frequencies of 1.5–3 kHz; the resulting responses were averaged before an outcome was given. A 'pass' was recorded in the presence of a confirmed TEOAE if a signal-to-noise ratio of +6 dB was achieved. An indeterminate outcome was recorded at a signal-to-noise ratio of +3 dB, indicating low TEOAE activity, excess background noise or an ill-fitting probe. A 'fail' was recorded when no valid TEOAE was detected. The outcome of TEOAE testing was recorded as either pass, 'inadequate' or fail, using a modification of the system employed by Owens *et al.*[7]

Testing was performed only in ears in which grommets had been inserted.

Statistical analysis

An initial descriptive analysis was performed on the study population. The sensitivity, specificity, positive predictive value and negative predictive value of TEOAE testing for detecting hearing loss were calculated, excluding responses that were inadequate. An unweighted Kappa coefficient was used to determine the correlation between the outcomes of the PTA and TEOAE investigations. Statistical analysis was conducted using the Stata version 9.0 software program.

Results

Seventy-two children were recruited into the study, of which 48 met the inclusion criteria. These children's mean age was 6.2 years (range three to 16 years).

Of these 48 patients, five underwent unilateral grommet insertion while the remainder ($n = 43$) underwent bilateral insertion (giving a total of 91 ears). Shah grommets were used in 78 ears (86 per cent) and collar button tubes in 13 ears (14 per cent).

At follow-up PTA, thresholds of 20 dB or less were found in 85 ears (93.4 per cent). Two ears (2.2 per cent) demonstrated thresholds of 25 dB at two or more frequencies, while four ears (4.4 per cent) had thresholds of ≥30 dB at two or more frequencies.

Transient evoked OAE test results were recorded as a pass in 69 ears (75.8 per cent), inadequate in nine ears (9.9 per cent) and a fail in 13 ears (14.3 per cent) (Table I).

After excluding ears in which responses were inadequate, the sensitivity and specificity of TEOAE testing for detecting hearing loss of ≥30 dB were 100 and 88.5 per cent, respectively. The positive predictive value of TEOAE testing for detecting hearing loss of ≥30 dB was 30.7 per cent, and the negative predictive value was 100 per cent ($\kappa = 0.43$). The sensitivity and specificity of TEOAE testing for detecting hearing loss of ≥25 dB were 66.7 and 88.2 per cent, respectively. The positive predictive value of TEOAE testing for detecting hearing loss of ≥25 dB was 30.7 per cent, and the negative predictive value was 97.1 per cent ($\kappa = 0.36$).

Discussion

This study found no absolute correlation between hearing thresholds and the presence of transient evoked OAEs (TEOAEs).

Transient evoked OAEs were first demonstrated in 1978 by Kemp, who showed that they were absent in

TABLE I
PTA AND TEOAE TEST RESULTS

TEOAE result	PTA threshold (dB)			Total
	≤20*	25†	≥30‡	
Pass	67	2	0	69
Fail	9	0	4	13
Inadequate	9	0	0	9
Total	85	2	4	91

Data represent number of ears. *Air or bone thresholds ≤20 dB; †air or bone thresholds of 25 dB at ≥2 frequencies; ‡air or bone thresholds ≥30 dB at ≥2 frequencies. PTA = pure tone audiometry; TEOAE = transient evoked otoacoustic emission

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the majority of patients in whom PTA thresholds exceeded 30 dB.[2] Robinette performed a systematic examination of 265 patients with hearing thresholds of 25 dB or less, and found that TEOAE responses were present in all cases.[8]

For practical purposes, the presence of TEOAEs suggests that hearing thresholds are less than 25–30 dB.[1,2,8] In the current study, hearing loss of 25 dB or greater was demonstrated in six ears. Of these six, two ears had audiometric thresholds of 25 dB at two or more frequencies, while four had thresholds of 30 dB or greater at two or more frequencies. In all four ears with audiometric thresholds of ≥30 dB, TEOAEs were absent. Thus, in this study, the sensitivity of TEOAEs for detecting hearing loss of ≥30 dB was 100 per cent.

The two ears with thresholds of 25 dB both had detectable TEOAEs. This suggests that the use of TEOAE testing in this setting may miss some cases of mild hearing loss (i.e. 20–25 dB). The sensitivity of TEOAE testing for detecting hearing loss of 25 dB can be seen to fall accordingly (being 66.7 per cent in this study).

While grommets have been shown to reduce the amplitude of TEOAEs, TEOAE responses have previously been detected in ears with grommets in situ.[7,9]

Daya *et al.* performed TEOAE testing in 32 patients following grommet insertion and found positive TEOAE responses in 76 per cent of ears tested; this finding correlates closely with our own results (i.e. 77 per cent).[9] In Daya and colleagues' study, which included 13 patients under three years of age, TEOAE testing was possible in 78 per cent of patients, whereas PTA was only possible in 59 per cent. This highlights the problems associated with performing PTA in young children, and the potential benefits of using TEOAE testing in this setting.

Another study, by Saleem *et al.*, prospectively investigated 90 ears, and found that pre-operative TEOAE testing had a sensitivity of 94 per cent for detecting hearing loss. In this study, all ears had normal PTA thresholds and TEOAE results post-operatively.[6]

Charlier and Debruyne conducted TEOAE testing on 106 ears with ventilation tubes in situ and normal hearing thresholds, and found TEOAEs to be present in 86.7 per cent of ears tested.[10]

However, in the latter two studies, normal post-operative PTA thresholds meant that the authors were unable to calculate the sensitivity of TEOAE testing for detecting hearing loss in the post-operative setting.

The results of the present study highlight some disadvantages of TEOAE testing as a screen for hearing loss following grommet insertion. The positive predictive value was low, and in nine of the 91 ears (9.8 per cent) the results of TEOAE testing were inadequate. In the clinical setting, any patient with inadequate or failed TEOAE test results would undergo PTA; in the present patient population, this would mean that 18/48 patients (37.5 per cent) would have required retesting.

Despite these limitations, TEOAE testing may still be viable as a screening tool for hearing loss following grommet insertion, particularly when patients are not compliant with PTA.

- **Pure tone audiometry (PTA) after grommet insertion can be time-consuming and difficult in uncooperative patients**
- **Transient evoked otoacoustic emission (TEOAE) testing offers an alternative means of hearing evaluation in this setting**
- **There is little data available on the sensitivity of TEOAE testing in detecting hearing loss after grommet insertion**
- **In this study, the sensitivity of TEOAE testing for detecting hearing loss was 100 per cent for ≥30 dB loss but only 66.7 per cent for ≥25 dB loss**
- **Transient evoked OAE testing may have a role in evaluating patients uncooperative with PTA, following grommet insertion**
- **However, TEOAE testing may miss some cases of mild hearing loss**

In order to compare the outcomes of PTA and TEOAE testing in individual patients, those who were not compliant with both tests were excluded from the study. This effectively meant that children under the age of three years were excluded, as they are not usually compliant with PTA testing. However, it is in just this age group that TEOAE testing offers the greatest benefit, as such patients are often the most difficult to assess. Although such children were not included in the present study population, consideration could be given to extrapolating the results of this study to patients aged less than three years, for whom TEOAE testing would significantly reduce the difficulties associated with hearing assessment.

Conclusion

The results of this study suggest that transient evoked OAE (TEOAE) testing offers a sensitive means of detecting hearing loss of 30 dB or greater, following grommet insertion in children. However, the use of TEOAE testing as a screening tool in this context may be limited by its tendency to miss some cases of borderline hearing loss.

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