Driving change for the better in occupational health surveillance for noise induced hearing loss

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INTRODUCTION

As the enforcing authority for the Control of Noise at Work Regulations 2005 (HSE, 2006) in Great Britain, the Health and Safety Executive (HSE) has responsibility for producing guidance and providing advice to assist employers in meeting their legal duties under this legislation. This includes providing guidance and advice for employers where they need to meet a duty under Regulation 9;

'If the risk assessment indicates that there is a risk to the health of his employees who are, or are liable to be, exposed to noise, the employer shall ensure that such employees are placed under suitable health surveillance, which shall include testing of their hearing.'

Health surveillance is a programme of systematic health checks to identify early signs and symptoms of work-related health in order for actions to be taken to prevent ill health progression and protect workers. The results of health surveillance are fed back to inform the risk assessment, risk management and review of control processes.

Current guidance on noise health surveillance details regular hearing checks via audiometric testing as the recommended method (HSE 2006). This method involves presenting sounds of fixed frequencies and varying intensities to the ear. Pure Tone Audiometry (PTA) is a subjective, behavioral measurement of hearing threshold, as it relies on patient response to pure tone stimuli. PTA involves presentation of pure tones to each ear at specific frequencies, so that the configuration of a hearing loss can be identified.

Awareness and control of noise at work has moved on immensely since the early 1980's, when the Medical Series guidance note; MS26 "A guide to audiometric testing programs" (no longer in circulation) was first published, yet we are still using the same method for health surveillance. PTA has come under some criticism in its limitations as a tool for occupational health surveillance as follows;

- The method only detects hearing damage at a level where damage is significant enough to affect the ability to hear pure tones. This damage is permanent and irreversible and may have been accumulated over many years of exposure alongside age related deterioration.
- There is a time lag between hazardous exposure and damage being detected, causing difficulties in the method being able to provide a timely preventative approach to revisiting the risk assessment and controls.
- The methodology requires strict test conditions in order to ensure quality of the results. This also compromises repeatability, which is an essential element of a health surveillance tool. That is in order to make judgements on effects of workplace exposures comparisons are made with previous test results.
- The test is subjective and requires cooperation from the individual being tested to respond to the pure tone signals being presented. Therefore uncooperative or untrustworthy individuals will not produce useful results.

HSE is interested in exploring options to improve the standards of noise health surveillance to assist dutyholders in meeting the aspirations of a robust occupational health surveillance model that enables early detection of signs or symptoms of ill health and useful and timely data that can enable preventative actions in reducing irreversible noise induced hearing damage.

One of the most promising advances in audiological testing has been the discovery of otoacoustic emissions (OAE) testing. This method has widespread application as a simple, non-invasive, test for hearing defects in newborn babies and in children who are too young to cooperate in conventional hearing tests. Many western countries now have national programs for the universal hearing screening of newborn babies. OAEs are responses generated by outer hair cells of the inner ear when stimulated by sound transmitted via a small microphone placed in the ear canal via an ear plug. OAEs have been widely shown to be depressed by noise exposure. HSE are interested in working closely with researchers, manufacturers, the audiological and occupational health community in fully exploring the potential of this method for application in occupational health surveillance.

METHODS

Following years of interest in the potential of OAE testing in occupational health, HSE decided it was timely to take action to make a concerted effort to achieve consensus on the way forward for research and practical application of this test method. An international expert symposium on the usefulness of OAE testing in occupational health surveillance was arranged to take place in Manchester on the 8-9th February 2011. This event managed to attract the attention of worldwide leading researchers and practitioners in this field. A list of participants is given in Table 1.

Table 1: List of participants attending International Expert Symposium on the usefulness of OAE Testing in Occupational Health Surveillance, 8-9th February 2011, Manchester UK

Anil Adisesh	Health & Safety Laboratories, UK
Stephen Archer	Occupational Health, Metropolitan Police, UK
Borka Ceranic	St Georges Hospital, London, UK
Alison Codling	Health & Safety Laboratories, UK
Clare Forshaw	Health & Safety Executive, UK
David Fox	Health & Safety Laboratories, UK
Hiske Helleman	Academic Medical Center, Netherlands
Agnès Job	Centre de Recherches du Service de Santé des Armées (CRSSA), France
David Kemp	The University of Central London, Ear Institute, UK
Mark Lutman	Institute of Sound and Vibration Research, University of Southampton
Lynne Marshall	Naval Submarine Medical Research Laboratory, Groton, Connecticut
Arturo Moleti	Dipartimento di Fisica - Universita' di Roma Tor Vergata
Annie Moulin	French National Center for Research (CNRS)
Brian O'Reilly	Occupational Health, Metropolitan Police, UK
Kerry Poole	Health & Safety Laboratories, UK
Dil Sen	Health & Safety Executive, UK
Rob Shepheard	Consultant Audiologist, SPIRE Hospital Norwich, UK
Renata Sisto	Italian National Institute of Occupational Safety and Prevention (ISPESL)

The aims of the event were

- to discuss the potential of OAE for use in occupational health surveillance,
- to explore the current scientific position,
- to discuss the barriers involved in advocating this new method,
- identify the gaps in understanding and
- decide where do we go next.

Following a series of presentations by the participants on their areas of interest and expertise in this area the group present at the meeting were invited to discuss and debate their experience and scientific knowledge based around a series of key issues presented by HSE at the meeting. These key issues were developed from a review of the literature undertaken by HSE and the Health and Safety Laboratory (HSL), which identified relevant gaps in the research evidence (unpublished). These gaps were identified in the context of what HSE expect OAE to deliver within an occupational health surveillance program.

The facilitated session aimed to reach consensus amongst the participants on the relevant issues to the usefulness of OAE testing in occupational health surveillance based on scientific evidence and expert agreement. Participants present were asked to agree points of consensus where they felt there was strong scientific evidence. The key issues tabled for discussion at the symposium facilitated session are given in Table 2.

Table 2: Key Issues Tabled for Discussion at the Symposium

• What is the relationship between OAE and NIHL?
• **Relevance of OAE testing for use in occupational health surveillance**
• What qualifies as an acceptable OAE measure?
• What change in emission is needed to indicate abnormality?
• Distortion Product vs Transient Evoked OAE measures
• What are the most appropriate test parameters?
• **What is the practical value/added benefit?**
• Are there any limitations to this method that would reduce its usefulness in health surveillance?
• **Gaps/Barriers. Taking the Work Forward**

The following report documents the key areas of discussion relevant to the aims of the session and the consensus points agreed. Where consensus was not reached this does not mean there is no evidence or that there is no support for usefulness in this area. It reflects a lack of consensus on strength of evidence amongst the group, a need for further research, or no clear understanding at this time.

RESULTS

The following provides a summary of the key points discussed by the group under the main headings given in Table 2 and the consensus points reached.

What is the relationship between OAE and Noise Induced Hearing Loss?

The facilitated session first considered the general concept of using OAE within an occupational health setting. Through discussion it soon became apparent that there is a need for agreed common terminology in discussions and reporting in this area.

The group concluded that the exact purpose of the role of OAE testing within an occupational health surveillance program needed to be established before usefulness

and applicability could be agreed. For example, there was a lack of clarity as to whether health surveillance aimed to follow grouped data to identify 'at risk' groups or whether the main purpose was to longitudinally follow individuals for the progression of hearing loss or damage.

There was some discussion on what health surveillance for noise induced hearing loss (NIHL) aims to achieve. Table 3 summarizes the thoughts of the group on the strength of evidence for OAE use under a number of potential aims of occupational health surveillance.

It was agreed that the evidence base for the usefulness of OAE is different for monitoring the effect of noise exposure in a health surveillance program on individuals and groups of workers. The participants agreed that there is strong evidence to support the use of OAE testing to longitudinally monitor groups of similarly exposed individuals and to identify 'at risk' groups at an early stage.

'At risk' was found to be difficult to define as the process of damage to outer hair cells picked up by OAE testing and the resulting hearing loss eventually picked up by PTA is not fully understood. However, it was felt there could be confidence that we are identifying subclinical changes to outer hair cells as a result of exposure to noise, which we know is likely to have an effect on hearing ability in the future.

Table 3: Summary of the Symposium Delegates views on evidence for the usefulness of OAE in Occupational Health Surveillance

Aim of occupational health surveillance	**Evidence for relevance of OAE supported?**	**Comments**
Prevention of damage	Possible	
Feedback to employer on effectiveness of controls	Yes with grouped data strong support	
Individual management of health effects	A possibility but, not strong evidence yet	
Identification of clinical damage/diagnosis	Evidence is sufficiently strong, depending on the specific diagnostic task and the population under test	
Biomarker of potential health effect	Yes, depending on the population and diagnostic task	
Biomarker of exposure	Yes, depending on the population and diagnostic task	
Identify effect of exposure for all workers?	No	Only useful when good OAEs can be measured

The evidence base supports use of OAE testing for individuals with good OAE emissions at test. As long as there are demonstrable emissions at a baseline test then OAE testing has value for monitoring individuals.

A consensus view on how a health surveillance program would be structured was to set a baseline with OAE and PTA. Following this periodical monitoring with OAE and only PTA where OAE produced 'abnormal' results i.e. large changes in emissions. We are not yet at a stage where we would not expect PTA to be a part of a health surveillance program for NIHL.

Relevance of OAE for use in occupational health

- There is evidence for a direct correlation between OAE and NIHL, BUT this is not a 1:1 relationship. This is due to the impact of non noise related issues on other parts of the auditory pathway.
- There is evidence for a well-established causal link between OAE and NIHL in groups of individuals via histopathological studies, animal studies, cross-sectional studies and empirical/anecdotal evidence.
- The evidence base supports use of OAE testing for individuals with good OAE emissions at test
- OAE reflect outer hair cell damage and outer hair cells are the most sensitive auditory function to noise damage
- OAEs can therefore have an important role as an earlier indicator of damage/effect of noise exposure
- OAEs also have a role in identifying temporary threshold shift (TTS) which can be very useful in demonstrating the effect of noise exposure. There is evidence that permanent nerve damage can accumulate from TTS
- There is a need for the development of an agreed standard operating protocol specific to why the test is being performed.

What qualifies as an 'acceptable' OAE measure?

In response to this question the participants again referred to the need to understand exactly what we want the test to do. There is an issue of reproducibility of results when emissions are near the noise floor. However, the noise floor is not the sole determinant of a good recording. The key aspect would be to achieve a good Signal to Noise Ratio (SNR). The group considered that it would be difficult to monitor results longitudinally if the testing program began with an emission near the noise floor as this erodes reproducibility. Conversely, the results would be considered significant if there was a sudden change from a strong emission moving towards the noise floor. As with PTA, quality assurance issues are important when using the equipment but if good signals were correlated with good thresholds then you could be confident of reliable measurements.

What change in emission is needed to indicate abnormality?

The participants acknowledged that there was difficulty in providing an agreed validated reference point for consistent and standardized advice in this area due to the lack of a normative reference population data.

Distortion Product OAE vs Transient Evoked OAE Methodology

Neither test covers all the frequencies of interest for NIHL. Distortion Product OAE (DPOAE) has strengths in that recent research has shown you can usefully separate the more specific frequency components. The strengths of Transient Evoked OAE (TEOAE) testing are that both click or Maximum Length Sequence (MLS) versions of the methods test a large proportion of the cochlea simultaneously. The group concluded that current evidence supports a combination of both DP and TE OAE methods following each other as a fast and effective way of OAE testing.

What are the most appropriate test parameters?

The participants considered this question but agreed that the most appropriate test parameters would depend on what you want the test to do i.e. different test parameters would be required when testing for vulnerability of future hearing loss ('at risk') and looking for mild hearing loss.

It was agreed that care would need to be invested in the testing procedure to ensure good quality emissions and a range of frequencies should tested and an average taken. DPOAE is currently the method with the most evidence to support its application in this field. However, further research may develop stronger evidence for other methods. There is a need for the development of an agreed standard operating protocol specific to why the test is being performed.

The group noted a need for commercially available equipment geared at occupational use to facilitate research and practical application. The present trend in clinical applications of OAE diagnostics is to propose user friendly instruments based on low frequency resolution DPOAE or conventional TEOAE recordings. Such instruments do not fully exploit the diagnostic potential of OAE. Participants discussed high spectral resolution DPOAEs and Stimulus-Frequency OAEs (SFOAES) as promising techniques for detecting quality frequency specific OAE response

Practical value of OAE. Added benefit to PTA program alone

- Objectivity
- Specific to outer hair cell damage which is the most vulnerable of auditory pathway to high noise
- Detects small changes in the cochlea or in the middle-ear functioning
- Somewhat less stringent test environment than PTA, although this remains an important test in a robust health surveillance regime
- Quick
- 3 stage approach
    - Baseline PTA & OAE
    - Interval OAE monitoring
    - PTA as and when problems identified
- Can alert to other auditory health conditions affecting the cochlea or middle ear.
- Key tool for motivational and educational purposes.
- Can reduce employer liability
- OAE has a key role as part of holistic approach to hearing conservation
- The disincentive to investment in advance of PTA techniques is due to the subjective nature of the test and the time factor in achieving increased sensitivity in PTA testing.

Limitations for application in occupational health surveillance

- Lack of normative data
- Training of technicians is needed, particularly on probe fit and blocking
- If there is a change in OAE is it necessary to eliminate middle ear cause
- Tympanometry should be undertaken, particularly at a baseline OAE test (this is more important when setting up an OAE program of test than for PTA)
- Need to ensure no occlusion of the ear canal

- Age may be an issue. However, if emissions are strong enough to allow room for decline to be detected then no problem
- Consensus that under the age of 40 are likely to provide 'cleaner' data
- Hearing threshold levels higher than 30-40dB cause the OAE response to fall close to the noise floor, making the SNR too low to achieve accurate diagnostic information. However, as OAEs are frequency specific, subjects affected by severe hearing loss at certain frequencies, may still have sufficient OAE at other frequencies to be able to usefully monitor effects of noise exposure here.
- The different temporal behavior of temporary shifts in OAE levels and audiometric thresholds following exposure to high impulse noise levels suggest that time after exposure should be considered a key parameter to be controlled in health surveillance
- OAEs depends on stimulus level and test parameters so these need tight control and agreed consistency to achieve comparable results

Gaps/Barriers and Taking the work forward

There was an agreed need to coordinate the development of a validated normal distribution of OAEs. The practicality of achieving this raised the issue that a standardized test methodology would need to be developed in the first instance. An agreement on standard terminology is needed and lack of commercial availability of equipment designed specific for application in occupational health is a current barrier.

In addition to a number of practical barriers there is also the need to influence behavioral change amongst all players involved in occupational health including employers, workers and occupational health professionals to bring about acceptance of the usefulness of the method.

CONCLUSION

There was consensus on many aspects of OAE use in occupational health surveillance. The event has stimulated ideas for collaboration amongst the participants and an electronic forum has now been set up for sharing relevant data to provide a more robust evidence base and the potential for pooling of data for future research is being explored.

- The group agreed that there is strong evidence to support the use of OAE testing to longitudinally monitor groups of similarly exposed individuals and to identify 'at risk' groups
- There is evidence of the usefulness of OAE in the early detection of 'at risk' groups following noise exposure from 'normal hearing' populations.
- The evidence base supports OAE use in individuals who have clear emissions at recruitment into the program
- A combination of both DP and TE OAE methods following each other promises a fast and effective way of OAE testing at this time
- The noise floor should be as low as practicable but should not restrict testing of individuals who show good SNR.

Next steps for the core group working in collaboration were to;

- agree some common terms and their meaning in respect of discussions and reporting in the use of otoacoustic emissions testing and occupational health.

- facilitate collation of normative data as a reference point to establish age related 'norms'.

Other issues which need addressing are

- The need for an internationally agreed standard operating protocol for OAE testing in occupational health situations.
- The need for commercially available equipment geared at occupational use to facilitate research and practical application.

The symposium has provided a platform upon which we need to build the science in areas where there is doubt and promote the usefulness of OAE in the areas where there is belief amongst experts that there is robust evidence of potential benefit in reducing ill health caused by noise at work. The symposium has provided a forum for future collaboration and sharing of ideas amongst leading experts and HSE. It is hoped that this event has been a catalyst to inspire future research to focus on the usefulness of OAE in occupational health and also be useful in persuading the occupational health community in general of the added value OAE can bring to preventative risk management of noise health risks.

REFERENCE

HSE (2006). Controlling noise at work. The control of noise at work regulations 2005 (L108): HSE Books.