General

A modern approach to noise induced hearing loss in military operations

D C Brown and R S Milner

Introduction
On 7th December 2009 at University College London’s Ear Institute, ‘A Modern Approach to Noise-Induced Hearing Loss from Military Operations’ brought together interested parties from the armed forces, the NHS, academic research and the voluntary sector to share and update knowledge of the science relevant to noise induced hearing loss and the practical problems faced during military operations.

Background
In 2006, due to increasing concerns regarding hearing loss resulting from operational noise exposure both from anecdotal reports and evidence from basic epidemiological surveys, Surgeon General (SG) mandated the chair of the Tri-Service Speciality Board Occupational Medicine (TSSBOM) to set up a Defence Hearing Working Group (DHWG) to formally investigate and address the issue of hearing loss across lines of military activity, especially the current operational environment. The current Chair of TSSBOM and DHWG is Surgeon Captain Brown, the Medical Officer in Charge of The Institute of Naval Medicine (INM).

A specific area of concern for all parties was the smooth transition of healthcare for service personnel when they leave service and their healthcare reverts to the National Health Service (NHS).

The Symposium
The symposium was opened by Deafness Research UK Chief Executive Vivienne Michael who stated: ‘We are delighted to be working in partnership with the MoD to help identify and minimise the risk of deafness and associated hearing conditions, and to offer practical advice and guidance based on the most up-to-date deafness research’. This was followed by an introductory address by Mr Kevan Jones, Under Secretary of State and Minister for Veterans. The Minister said: ‘The support that our people deserve is out there and we want to make sure that they can take full advantage of everything that the MoD and charities such as Deafness Research UK provide.’ The Minister added that he acknowledged the achievements of the DHWG, whose members include a representative from Deafness Research UK. There was also participation from the United States (US) Department of Defense and US Veterans Administration. Presentations and discussion were focused on four key areas:

- Reviewing NIHL: Why Now?
- Aetiology of NIHL
- Limiting NIHL
- Management of NIHL

Abstracts from presentations are presented below.

Reviewing NIHL: Why now?

Noise Induced Hearing Loss in the Ministry of Defence – role of Defence Hearing Working Group
Surgeon Captain David Brown QHP FFOM
Royal Navy - Consultant in Occupational Medicine in the Royal Navy

The issue of noise induced hearing loss as a result of military operations was recognised
in the immediate aftermath of the two World Wars, where personnel were exposed to intensive combat, however hearing protection was limited to the use of fingers and cotton wool. Subsequent to World War 2, and with the introduction of new military equipment including jet aircraft, major advances were made in the assessment of noise exposure and control measures, including hearing protection, thereby minimising the risk to service personnel. MOD made major efforts to comply with the Health and Safety at Work Act and subsequent Noise at Work regulations, and introduced comprehensive hearing protection programmes. Although weapon noise was long recognised and assessed as a hazard, with Peak Exposure Levels well above 140dB, it was able to be controlled by hearing protection. However, after the increase in military activity in Afghanistan from 2006 onwards it became clear that individuals were returning from theatre with Noise Induced Hearing Loss. Urgent action was taken by Land Command to mitigate this risk, and Surgeon General established the Defence Hearing Working Group to bring together all parties involved in the identification, prevention and management of noise induced hearing loss. Progress to date will be outlined and enlarged upon in subsequent presentations.

Operational Perspective
Col W. Bramble, AD PERS OPS - Chairman of the Army Hearing Working Group

Context:
- Deployability of Army. Army manning has a proportion that is either Non Deployable or limited deployable. Including reference to those Soldiers employed on tasks.
- Casualty figures. Cover the current level of casualty figures in order to understand that Hearing Loss (HL) is part of the wider casualty management activity.

Occupational and Environmental Context.
- Magnitude of Problem. After HERRICK 6 (Apr 08) HQLF received indication that HL was a problem generated on ops. This coincided with the work by SG and the US on their Fallujah experiences. The resulting early analysis of available audiometry showed the average infantry battalion HL was approx 6% of held strength. Those infantry battalions returning from Afghanistan (AFG) on HERRICK 6 showed HL statistics of up to 14% of held strength.
- Health Surveillance/ Audiometry. The requirement is set by JSP 346 for medical occasions (pre employment screening, routine PULHHEEMS occasions, for medical problems and when leaving the service). Audiometry requirements due to Noise at Work regulations are contained in Army Hearing Conservation Programme which set bi annual (every 2 yrs) audiometry requirement with increased frequency for those at higher risk. As a result of these early indicators from troops returning from AFG, it was decided, in Jun 08, that annual audiometry for all personnel would occur. Furthermore, all personnel deploying on operations to AFG must have a pre deployment audiogram within 6 months of deploying and a post deployment audiogram within 6 months of returning from ops.
- Operational Experiences. Operational experiences since Falkland Islands (Balkans, GRANBY, TELIC) have not exposed HL as a significant issue due to the nature of conflict and operating environment.
- AFG Operational Environment. However, nature of conflict in AFG, which is significantly different has shown that the in service Hearing protection systems, particularly for those engaged in dismounted close combat, were ergonomically and functionally sub optimal. Critically, the imperative to utilise all your senses to maximise situational awareness whilst engaged in dismounted close combat in complex terrain and fighting a counter insurgency operation forced many to make a stark choice of retaining situational awareness (including maintaining radio communications and verbal orders) as a short term life
preservation essential subordinating the risk of HL to worry about if you were lucky enough to live to retirement. Furthermore, the nature of counter insurgency (COIN) operations, and particularly in AFG, is such that there are very practical reasons why Hearing protection may not be worn at the critical moment and when you are least expecting it.

- Formation of the Army Hearing Working Group. Met on 1 May 08 with aim to identify HL problems provide a single army focus for HL and link into the Defence Hearing Working Group. The tasks of the AHWG are to understand the problem; review and develop policy; issue direction; improve Health Promotion through education and culture change. Finally, the Personal Interfaced Hearing Protection system, which you will hear about later, was brought into service as a result of the AHWG catalysing efforts.

- Conclusion. There has been much progress in terms of policy development; Health surveillance and monitoring; Health promotion and culture change; as well as new equipment for those deploying on operations. Prevention and early identification remain the best way of approaching the issue of Hearing Loss. However, consequence management remains a key area that we are focused on in order to address those with Hearing Loss.

The extent of operational noise-induced hearing loss

Surg Cdr C Pearson MBA MA FRCS (ORL) RN
- Defence Consultant Adviser in ORL

A diagnosis of noise-induced hearing loss requires a history of exposure to sufficient noise and audiometric evidence of a high-frequency hearing loss of the appropriate configuration. Whereas exposure in industry may be assessed relatively simply, sporadic exposure to very high levels of noise generated by weapons means that this is not the case in the operational environment. In the Service hearing conservation programme it is, therefore, necessary to place greater reliance upon individuals’ audiograms.

Newspaper reports in 2008 implied that between 5% and 10% of troops had become non-deployable due to NIHL on recent operations, but audit of their medical records shows that this was so in only one-third of cases.

Comparison of pre- and post-deployment audiometry in 100 Reserve personnel who deployed in Op Herrick 6 showed that 10% had a definite deterioration in their hearing and a further 32% had a measurable loss.

Of 181 Royal Marine 42 CDO troops who deployed in Op Herrick 9, 69% had audiograms that were consistent with NIHL. Both the proportion of affected individuals overall, and the proportion who were affected to a greater extent was significantly greater than a baseline study of RAF personnel that was undertaken prior to Op Herrick and Telic.

Aetiology of NIHL

Introduction to the ear, hearing and the effect of noise

Prof David Kemp - Emeritus Professor of Auditory Biophysics at University College London and Founder and Director of Otodynamics Ltd

The ear is a sensitive and delicate mechanism normally able to respond to ear drum movements smaller than the size of an atom. Today’s researchers’ access powerful techniques which can help us visualise the intricate mechanism of the ear at work. Much more than just a microphone- the ear is an energetic machine able to manipulate, amplify and analyse sound energy on a nanometre scale before it is passed to the brain.

Its long been known that intense or persistent noise can permanently erode hearing sensitivity but the exact location and nature of this damage was unclear. Today we know that it is the energetic ‘engines’ of the ear – the ‘outer hair cells’ - which suffer most from the physical and biological stresses induced by noise. They become deactivated and eventually die causing a thousand-fold loss in hearing sensitivity. We
can record the progression of this damage with forensic precision. Strengthening and even restoring these cells may be an option in the future but the immediate need is for practical means to detect the earliest signs of weakness in individuals before permanent hearing damage accrues. Genetic studies should explain why some ears are much more susceptible to noise than others.

**Tinnitus – Gain, Pain and the Brain**
*Professor David McAlpine - Professor of Auditory Neuroscience and Director of the Ear Institute*

Cochlear damage can trigger the development of central hyperactivity, but the underlying mechanisms remain elusive. Physiological studies indicate that the perception of tinnitus is linked to aberrant spontaneous activity (hyperactivity) of neurons in the central auditory system. Tinnitus-related hyperactivity has been found in the dorsal cochlear nucleus, the auditory cortex, and recently also in the inferior colliculus. Computational modelling indicates that activity stabilization through homeostatic plasticity could explain the development of hyperactivity and tinnitus. This presentation will describe some of the possible causes and consequences of tinnitus, including the possibility that noise-induced hearing loss not detected by conventional audiology, can elicit tinnitus symptoms. Mechanisms contributing to the tinnitus percept may be related to normal brain mechanisms that control sensory gain. The outcome can be likened to phantom limb pain, where the absence of sensory input is compensated for by modifications of the neural representation of the damaged or missing limb.

**Research into NIHL**
*Mr. Kurt Yankansas - US Office of Naval Research*

The presentation referred to the high incidence of noise induced hearing loss in DoD personnel with 3-7% of US Navy personnel showing a Permanent Threshold Shift and poor compliance with hearing protection. There is evidence of poor performance in response to operational commands by those with hearing loss. The issue represents over 16% of Claims for Benefit from the Veterans Administration with 9% for Tinnitus and 7% for hearing loss. There are major problems within the Naval environment particularly with flight deck personnel on carriers, 24/7 and impulse noise.

ONR’s current research programme includes investments in the following areas:

- Biotherapeutics and Susceptibility including research into prevention through biomarkers, mechanisms of injury and effects of noise, use of anti-oxidants, enzymes, anti cell death and cochlear hair cell regeneration.
- Investment in hearing aids and cochlear implants.
- Medical technologies: signal processing in cochlear implants, and drug delivery
- Evaluation and training: measuring susceptibility, predicting loss, evaluation of interventions and training tools
- Noise reduction
- Protective equipment including 3D ear canal digitalisation for customised ear plugs, in ear dosimetry, noise cancellation and communications

The long term aims are to reduce VA claims by 90% and improve hearing protection and communication systems. Perceived benefits include establishment of the mechanisms of tinnitus and NIHL and the impact of 24/7 exposure, the development of standards for impulse noise and 24/7 noise and suitable PPE for service personnel enabling appropriate communications, talk through, 3D audio and noise reduction.

**Limiting NIHL**
*Lieutenant Colonel SEF Folkes - Consultant Occupational Physician Army Medical Directorate*

Service life exposes personnel to many occupational hazards that differ from the civilian environment, in the non operational environment the risk of these hazards causing harm can be addressed and have been reduced to the lowest practicable level to meet and in
many cases better than that which is required
by the legislation. In the operational
environment, the increasing tempo of
operations and exposure to novel noise hazards
increases the risk of noise induced hearing loss.

The principles of reduction of exposure to all
occupational hazards also apply to noise
exposure in the military. The principles of limiting
exposure are laid out in a number of policy
documents JSP 375, 2006DIN07-008
Implementation of Noise and Vibration at Work
Regulations 2005 and in the Army this is further
interpreted in the and Forces Standing Order
3303 - Land Forces Hearing Conservation Policy.

Non-deployable Environment – key
identification of potential noise hazards this is
undertaken by line managers and unit safety
officers. Areas to cover are identification of
potential noise hazards, identify persons at
risk, arrange for a noise assessment, reduction
of risk, provision of appropriate hearing
protection, ensure arrangements are made for
health surveillance, hearing protection zones,
education, monitoring noise control measures
and consultations including Unit Health
Committees.

Operational and Overseas training
exercises - personnel are exposed to a wide
variety of potentially damaging noise sources
that cannot always be identified and managed.
As part of the health force protection
measures each operation and exercise has
specific measures and hearing protection
measures outlined in the mounting
instructions. Where possible the options must
be taken to taken to ensure the use of hearing
protection when predictable noise exposure is
planned e.g. wearing hearing protection when
transiting in an aircraft or armoured vehicles

Education
- Extensive work has been undertaken over
the last year to develop additional hearing
protection education material.
- Production of a 10 minute DVD ‘Listen to
Sense’ which is targeted at Service personnel
in Initial Training but for use throughout a
career to highlight the fact that hearing loss
can be caused by operational contacts, firing
weapons, operating machinery unprotected
or listening to loud music. Highlights hearing
loss is progressive, often painless and
permanent and importantly will have
significant effect on promotional chances and
the ability to deploy on operations. The DVD
is supported with additional material to guide
the presenter though the discussion that
should follow watching the film.
- Supported by Commanders guide and
Individuals Guide as well as posters x 3
- There have been slots on Garrison radio
complementing the Listen to Sense
programme and it is covered at Regional
Health Fairs.
- Army Net open will also shortly have a
Listen to Sense section with the
educational material.
- A 10 minute DVD, ‘Listen to Sense -
Protect Your Ears’ was shown to the
audience.

Screening
- Audiometry as Health surveillance is part
of the Army Hearing Conservation Policy.
- Frequency and means of testing, grading
and interpreting laid down in MOD policy
and further supplemented by single
service guidelines.
- JSP 346 pre-employment screening and
then SGPL 12/06 and 05/09 provide medical
guidelines. Army DGAMS policy letter 09/08
Health Surveillance for Noise at Work in the
Army and specific employment groups have
additional requirements e.g. aircrew.
- Army now require audiometry to be
undertaken pre-entry, at Service
PULHHEEMS, annually and within 6
months prior and after operational
deployment (this should fulfil annual
requirement, on discharge or retirement
and at the discretion of the clinician).

Hearing Protection Dismounted Infantry
Mrs Gillian Williams - SE CESO ASE Noise
DE&S
Defence Equipment and Support

Mrs Williams discussed the background and
range of equipment that MOD supplies to
meet the requirement before going on to cover
the MOD’s work towards procuring equipment to meet changing needs of infantry soldiers.

**Potential for pharmacological intervention in noise-induced hearing loss**
Professor Andrew Forge  
Centre for Auditory Research, UCL Ear Institute

With the exception of intense blast noise which causes complete, irreversible disruption of the sensory tissues of the cochlea, the major cause of noise-induced hearing loss (NIHL) is the death of the sensory “hair” cells. Once lost, hair cells are not replaced so the consequent functional deficit – hearing impairment – is permanent. Understanding the biochemical pathways that lead to hair cell death and how they are triggered by noise has indicated possible means for pharmaceutical intervention to prevent or ameliorate hair cell loss. One major trigger initiating the cell death programmed is excess production of “free radicals,” highly reactive forms of molecular species that breakdown cell components.

Noise exposure leads to free radical generation in the cochlea. Some potential “otoprotectants” target specific components of the cell death pathway, but these may difficult to deliver to the cochlea easily. A number of different “antioxidants,” which “scavenge” free radicals and neutralise them or enhance natural cellular scavenging systems, have been suggested to reduce the extent of noise-induced hair cell loss. Many of these chemicals are small molecules able to cross the physiological “barrier” between the blood supply and the cochlear fluids, and thus potentially could be taken systemically. However, the doses required, and for how long before and/or after exposure to traumatising conditions such dosing needs to continue are not known.

**Management of NIHL**

**Fitness for work and occupational rehabilitation for NIHL within the MOD**
Lt Col L Holder  
Defence Medical Services Department

The presentation will cover:
- Current UK hearing acuity grading system
- Linking this system to deployability on military operations
- A proposed future hearing acuity grading system
- Management of potential NIHL cases
- Looking at knowledge gaps (true prevalence, consistency and quality monitoring of audiometry)
- Opportunities to improve future knowledge – more research, use of DMICP data

**Integrating hearing and balance services: vision, benefits and challenges for populations who serve in armed forces**
Professor Adrian Davis BSc, MSc, PhD, FFPH, FSS, O.B.E  
Director MRC Hearing and Communications Group, University of Manchester Director of the Newborn Hearing Screening Programme for England.

There has been much debate about the extent to which noise exposure in young people affects their hearing in later life. There has been no formal consensus but an agreement that noise, especially the noise experienced by ex-service personnel, is a major public health issue in later life that needs to be addressed. Clearly prevention is best. But prevention is only part of the major issue which is how those who have immediate or later impacts of noise get the best quality services to reduce the impact on activities that people normally need to do or enjoy doing. The later impacts are usually dealt with reasonably effectively by the NHS, but the age at which people realize there is a problem is often too late. Recognition that ex service personnel are at raised risk of developing hearing problems needs to more widely disseminated and it is not unreasonable to think that a targeted screening programme would identify those with hearing problems that can be addressed by hearing rehabilitation would have substantial quality of life benefits. These should be routine innovations that could be introduced if there was a governance and funding stream agreed. But do we need to
think about equity as well? Beyond hearing loss the situation is more complex. It is not just hearing problems, but more complex issues regarding tinnitus, balance and other impacts that noise and trauma may create. The NHS is not necessarily well equipped to look at these longer term more complex issues. How should it respond, what partnerships are necessary to improve current services and is there a need to establish a baseline for what NHS services ex service personnel are currently receiving for these problems?

US Experience
Stephen Fausti PhD - Director, National Center for Rehabilitative Auditory Research (NCRAR)

- Auditory dysfunction is the most prevalent service-connected disorder
- One in four service members returning from OEF/OIF conflicts complains of hearing loss and/or tinnitus (Fallon, 2006)
- As the Veteran population ages, hearing loss will become more prevalent and more Veterans will require rehabilitation
- Effective hearing loss prevention strategies must be implemented in order to reduce the financial and personal costs of auditory disabilities
- For the veteran, the most relevant cost is the reduction in "readiness for life"

Closing summary and audience feedback

Prof Mark Haggard
FMedSci HMFPHM HFRCSeD CBE
Honorary Vice President Deafness Research UK

It is hardly possible to provide a comprehensive summary of a diverse meeting such as this in a few minutes, or paragraphs. The 25 themes for carrying forward which I identified (in a process that was open to input from others during the day) covered 6 main areas. The first of these areas could even be considered as four: policy, compliance, education and incentives; technology; diagnostic assessment; standards; and managing consequences of NIHL. I took from the meeting an impressive intention to move on as rapidly as possible, that is from the recognition that Noise-induced Hearing Loss had not been a priority area for some 3 decades to a set of actions that would put appropriated technology and arrangements in place readily. This intention took the form of a willingness to identify problems, share and learn. I can perhaps do no better than illustrate these six areas with one example each, adding a rider that this represents less than a quarter of the issues which I listed, and more like an eighth if the more specific categories of suggestion from subsequent audience feedback are furthermore included.

In the context of policy and compliance, the Army video alerting soldiers to the consequences of hearing loss was well received by those to whom it was new, and judged an appropriate motivational support for the wearing of hearing protection where possible. It appealed, reasonably enough, to aims of the ability to work, the enjoyment of social life and the avoidance of marital discord. However it was raised in discussion that not all these them es will appeal to all categories of personnel, age being a main factor. There may be more to be discovered by qualitative research about the most influential themes for particular sets of people; accordingly, a profitable stratification into 2 or even more versions for differing target audiences, but calling on all the original footage, might be appropriate. Under diagnosis and assessment, the issue was raised as to whether a single diagnosis of NIHL is useful. Attributions to noise always involve a balance of probabilities as other factors are hard to rule out. So in an Armed Forces context would not, an impairment measure and a comprehensive history leading to the relative strength of exposure to noise relative to exposure to other possible causes not be more useful? This is an essentially administrative but answerable question.

The issue of field (ie late-stage, after laboratory performance testing) evaluation of
equipment arose in more than one context. Clearly opportunities for such intermediate testing become squeezed by pressures to get better equipment rapidly into the front line if there has been an identified problem. There are also many limits to the ability to accommodate R&D in theatre of war. But are we convinced that the right overall strategic chain exists between laboratory testing, simulated field conditions including performance and acceptability through a variety of methods, and systematic solicitation of feedback from early users that may optimise the instructions for use and in due course lead to further improvements? An obvious but not unique example is the new personal hearing protection built into communications equipment. Under the heading of evidence gaps, many suggestions were made for epidemiological research on NIHL within the military for aspects that should not be overlooked: genetics, nutrition, extra-military noise exposure and more refined measurement. Indeed in such a multi-causal phenomenon omission of any of these aspects improves the analysis of any specific one that may be in focus, through confounding or unnecessary measurement error. However it was widely recognised that progress had to be made in basic administrative systems that would capture health data on personnel in sufficient quantity and quality for it to become worth adding specific bolt-on measures from a research budget. The need for improvement embraces comprehensiveness of pre-operational and post-operational checks, completeness of follow-up and long term traceability of individuals who have left the armed forces. An epidemiological study with routine data and its management improved in such ways could serve many research questions. The escalating number of blast injuries makes a detailed study of their presentation and sequelae, including the correlation of auditory with other injuries, an urgent priority.

Fitness for employment already has an assessment system that has been revised within recent years, but it remains rough-and-ready, needing to capture all the main organ systems (eyes, limbs etc) as well as hearing, and it is not based upon the idea of continuous monitoring of readiness for battle. The idea of some single measurement technique or questionnaire that serves all purposes in a domain such as hearing has long had its day and any discussion of appropriate measurement must state the specific aim and context. In close-combat roles, wearing of hearing protection may be impractical or even dangerous; we do not question this verdict from front-line troops and the Army video on protection uses the point well. By the same principle, some mild early hearing losses must be considered similarly dangerous, and would justify redeployment away from the front line, with the possible added benefit of preventing further damage in the most susceptible individuals. There is not an accepted standard for the maximum impairment with presumed combat-noise cause that is permitted nor for this aspect of fitness for duty. Standards always pose challenges: the existence of any evidence base, achievement of consensus, and time-limited development via commissioned further work and appropriate measurement. Pure tone audiometry (PTA) is an important core assessment technique in all diagnosis and epidemiology, which chiefly quantifies gross degree of impairment. However new screening techniques which do not quantify impairment but detect minor departures from normality, for high frequencies where they most typically occur, could be as good as PTA for this specific purpose of confirming hearing normal enough for close-combat roles.

Under the final heading of managing consequences, the meeting may have been prescient. There has since been a ministerial announcement by the Department of Health of an initiative, with full MoD involvement, to improve the transition to care by the NHS and the service given by the NHS to former service personnel generally. There is now a consultation period over details of implementation and the Department has declared itself open to suggestions such as those that emerged at the meeting.

The feedback from the audience was analysed as a whole, not stratifying on military
versus non-military respondents. It was favourable concerning achievement of the main declared aims of the meeting and usefulness to participants. The further suggestions fell in three types: (a) topics for dissemination to spread awareness, (b) topics for debate with possible changes in policy or arrangements following, and so appropriate to further meetings (both within MoD and more widely); and (c) specific straightforward issues that can and should be worked up or actioned in the near future. Examples would be: (a) workshops to include MoD civilian personnel in promoting existing policy for hearing protection; (b) trials of drug prevention and therapy (for which there is some preliminary evidence); and (c) the improvement of technique, quality and data linkage of assessments within the existing medical service arrangements. It is characteristic of such consultation that a topic may not receive the correct classification initially eg it may raise more profound issues than at first seemed, so implementation might be premature. An extended meeting of the Armed Forces Hearing Group is to be organised shortly to take look at this classification and take forward several of the latter.

The powerpoint presentations are accessible at the following website:

http://www.deafnessresearch.org.uk/Charities%20praised%20by%20Minister%20for%20Veterans+5508.twl

Summary
The symposium successfully brought together key military medical and personnel managers with civilian experts in hearing disorders and charities to help streamline our knowledge of the aetiology, investigation, prevention and management of NIHL. A requirement for seamless medical care for veterans with NIHL was recognised and collaborative work has commenced.

Related reading:
ACOS Med Policy Letter 02/09 Requirement for Pre/Post Deployment Audiograms for Op Herrick