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Noise-Induced Hearing Loss in the United Kingdom: A Preventable Occupational Disease of the Industrial Revolution

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Abstract

Noise-induced hearing loss is one of the most common occupational industrial diseases and yet is entirely preventable by the use of appropriate hearing protection and/or noise reduction methods. The earliest references in modern literature date from the late 1700s to early 1800s where it was recognised as a clinical entity in blacksmiths and boiler makers. Noise-induced hearing loss was essentially a product of the industrial revolution as manufacturing processes became mechanised through the use of steam and internal combustion engines. In addition, the mining and delivery of iron ore and coal around these times was also associated with loud noise. The setting down of the foundation for prevention of loud noise exposure and hence deafness was not until 1963 (*Noise and the Worker*, Wilson Report) which established the so-called date of 'guilty knowledge' from which noise-induced hearing loss (and tinnitus) became a potentially compensable disorder. Furthermore, noise-induced hearing loss became a Prescribed Disease and thus pensionable under the Industrial Diseases Act of 1975. In respect of the diagnosis of noise induced hearing loss, clinical examination of the ear with an otoscope was not mainstream British practice until the 1920-30s and the methodology of diagnosing and quantifying hearing loss, that is pure tone audiometry, only became routine practice later with the development of reliable technology to present calibrated sound levels of known intensity.

Keywords

Noise-induced hearing loss, occupational disease, sensorineural hearing loss, pure tone audiometry

Introduction

This paper is concerned with placing in a historical context the otopathological effects of chronic, long-term exposure to noise in an industrial setting, known as noise deafness or noise-induced hearing loss (NIHL). This is distinct from sudden, short duration, high intensity noise such as would be sustained from gunfire discharge (known as acoustic trauma). Although some industrial processes do involve noise capable of causing acoustic trauma, the characteristic of most excessive occupational noise is a 'steady state' level over an entire working shift. In respect of military service, deafness following gunfire discharge has been recognised for over 300 years and indeed it is said that Admiral Rodney (1718-1792) was almost entirely deaf for a fortnight following the discharge of 80 broadsides from HMS *Formidable* in 1782.[1] Indeed, permanent damage to hearing can result from even one unprotected gunfire discharge where noise levels can exceed 140 decibels (dB, a logarithmic measure of the strength of a sound).[2] Noise levels as high as this are unlikely in most manufacturing processes and NIHL can in fact arise following exposure to much lower levels.

With long-term exposure to the noise of industrial processes, NIHL is usually insidious and of gradual but accumulating onset. Hearing loss produced by noise of this nature is sensorineural, meaning the damage takes place in the cochlea or inner ear. With short duration, high intensity explosive noise this also occurs but there can be associated middle ear damage if the noise levels are great enough, for example an associated rupture of the tympanic membrane and/or ossicular discontinuity.

Upon initial exposure to the noise of industrial processes the individual can become aware of a temporary dullness in hearing, for example noticeable at the end of a working day, and this is known as a temporary threshold shift.[3] This is in fact a normal response of the ear to noise, where hearing returns to the pre-exposure level after a short time. Such hearing loss can be accompanied by tinnitus, a sensation usually either of ringing or hissing in the affected ear, which again usually recovers with the improvement in hearing but not inevitably so. With continued exposure, temporary threshold shifts can become irreversible, known as a permanent threshold shift. Individuals in this situation may not notice hearing loss until many years of exposure to excessive noise (typically eight to ten) have passed when there is the onward progression of deafness of ageing (presbyacusis), the two summating.

With the advent of pure tone audiometry where precise hearing losses could be measured at specific frequencies, largely from the 1950s onwards, it became apparent that the maximum loss tends to occur in the 4 kilohertz (kHz) region of the inner ear. Possible explanations for this arise from anatomical considerations and resonant frequencies of the hearing mechanism. In addition, cardiovascular and nutritional factors are also thought to be relevant for the part of the inner ear, the Organ of Corti, that transducts acoustic stimuli into nerve impulses which pass along the VIIIth cranial

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[1] Mawson SR, Ludman H. *Diseases of the Ear: A Textbook of Otology, 4th Edition*. London: Edward Arnold; 1979.

[2] Fisher T, Gibbin K. *Synopsis of Causation*. London: Ministry of Defence; 2008.

[3] Ryan AF, Kujawa SG, Hammill T, Le Prell C, Kil J. Temporary and Permanent Noise-induced Threshold Shifts: A Review of Basic and Clinical Observations. *Otology & Neurotology*. 2016; 37(8): e271-275.

(vestibulocochlear) nerve to the central nervous system and are experienced as the sensation we perceive as sound. Maximal damage leads to selective hair cell loss in the Organ of Corti.[4]

It is said that Hippocrates (c460 BCE–c370 BCE) was aware that exposure to noise could lead to tinnitus but in more modern times damage to the ear from noise was recognised in the 1700s in coppersmiths and in 1831 this association was described by Fosbrooke in blacksmiths.[5] In 1886 Thomas Barr (1846–1916) described similar hearing loss in Glaswegian boiler makers and indeed as the effects of the Industrial Revolution swept through the developing world the prevalence of NIHL increased.[6]

The diagnosis of noise-induced hearing loss

As with any condition in medicine, diagnosis is established along the usual clinical lines from the history, examination and then recourse to certain investigations. Some form of otoscopic examination, that is visualisation of the deep part of the external ear canal, tympanic membrane and middle ear, was first described in 1363 by Guy de Chauliac (c1300-1368) in France using a form of speculum.[7] The modern otoscope, however, was largely derived from the work of Wilhelm Kramer (1801-1875) in 1881 and Arthur Hartmann (1848-1931) in 1890.[8] Various types of otoscope have been used over the years as shown in Figure 1. The image at the bottom of the photograph is the instrument described by John Brunton (1836-1899) who coined the term otoscope in 1865.

If individuals with NIHL are examined otoscopically, since the disorder is confined to the inner ear, normal appearances are expected since there is no external or middle ear damage. Nevertheless, the examination is important to exclude coincident or other causes of hearing loss, for example chronic suppurative otitis media (a perforated tympanic membrane in the presence of infection/inflammation) which was particularly prevalent in the pre-antibiotic era until relatively recently, the presence of occluding wax or indeed fluid in the middle ear space (a middle ear effusion). None of these is noise related but of course lead to hearing loss which confounds the diagnosis and which potentially are all reversible.

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[4] Yang WP, Henderson D, Hu BH, Nicotera TM. Quantitative Analysis of Apoptotic and Necrotic Outer Hair Cells After Exposure to Different Levels of Continuous Noise. *Hearing Research*. 2004; 196: 69-76.

[5] Rosenwinkel NE, Stewart KC. Hearing Loss Related to Non-Steady Noise Exposures. *American Industrial Hygiene Association Journal*. 1959; 20(4): 290-293.

[6] Atherley G, Noble W. Occupational Deafness: The Continuing Challenge of Early German and Scottish Research. *American Journal of Industrial Medicine*. 1985; 8(2): 101-117.

[7] Feldmann H. History of the Ear Speculum: Images from the History of Otorhinolaryngology Highlighted by Instruments from the Collection of the German Medical History Museum in Ingolstadt [Article in German]. *Laryngorhinootologie*. 1996; 75(5): 311-318.

[8] *Scott-Brown's Diseases of the Ear, nose and throat, Volume 2, The ear, 3rd Edition*. Ballantyre J, Groves J (Eds). London: Butterworths; 1971. Chapter1, Methods of examination of the ear, p.1-33.

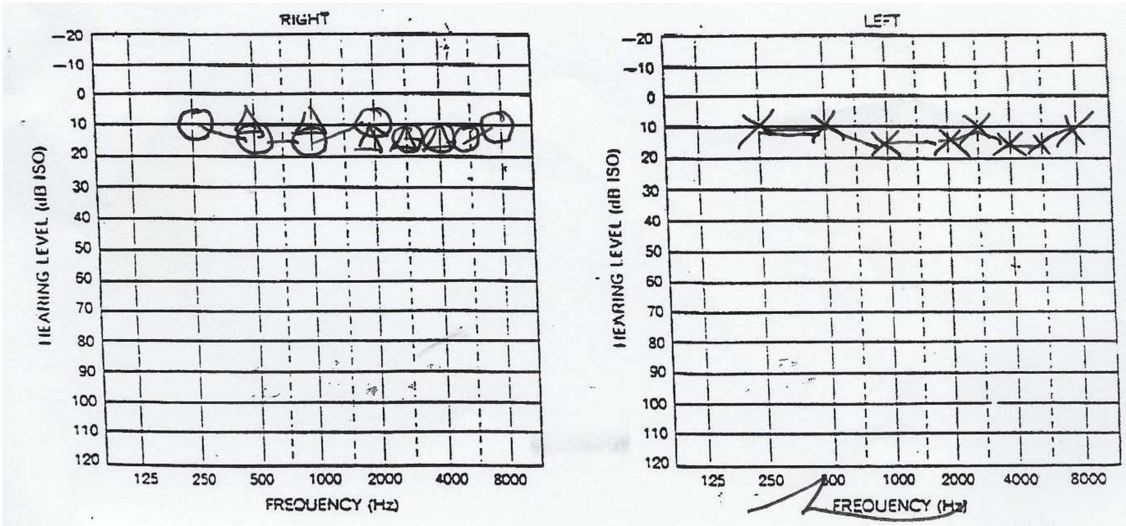
Figure 1. Otoscopes through the ages. The instrument at the bottom is that described by Brunton. Authors' collection.

An important advance in the diagnosis of NIHL came with the advent of pure tone audiometry which forms the principal diagnostic investigation. Clinical tests of hearing ability have been in use for over 200 years and some form of quantification of hearing loss was attempted using mechanical devices including ticking clocks, chimes and tuning forks. David Hughes (1831-1900), a pioneer of early telephony, became interested in this field and developed a device using an induction coil in 1879 as did Hartmann in 1885 but it was not until the development of thermionic valves and reliable devices to produce oscillations at audible frequencies in association with appropriate amplification using calibrated gains that pure tone audiometry became a mainstream investigation. This was largely due to the work of Edmund Fowler (1872-1966) in the 1920s where some of the current standards of pure tone audiometry including presentation of sound at octave intervals and the use of bone conduction measurements in addition to sound presented using conventional headphones (air conduction) were set down.[9]

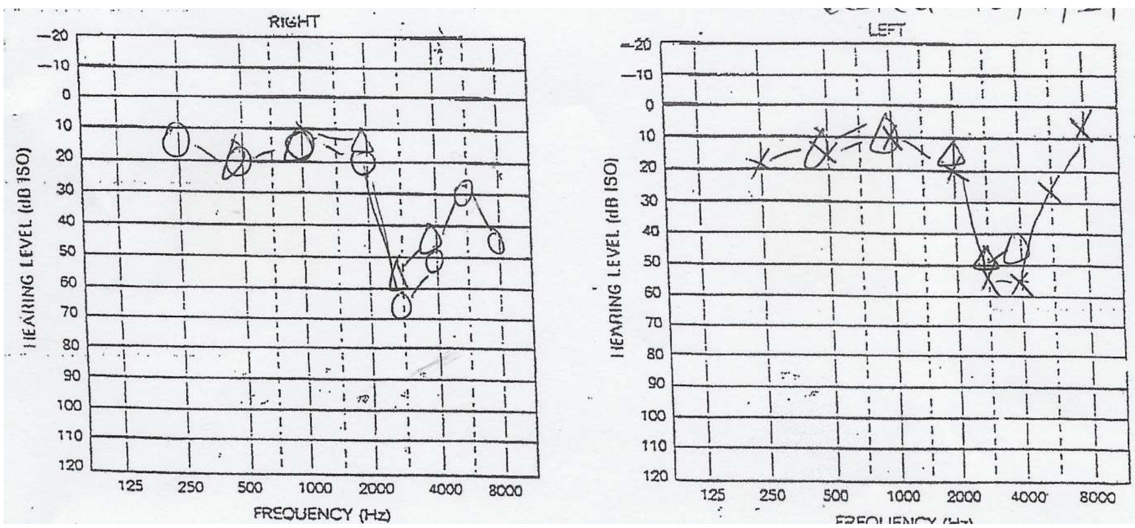
A scale of the intensity of sound known as the decibel was developed for telecommunication use in the early twentieth century by workers in the Bell Telephones Corporation USA. Since the human ear does not perceive growth of loudness in equal increments of sound energy the decibel scale is logarithmic in nature and consists of a ratio comparing two sound intensities one of which is at a reference level of 20 micropascals (μPa) and that presented to the individual under test. Pure tone audiometry therefore became established in clinical practice and was more-or-less universal from the mid-1950s onwards and indeed is widely used in present times. In this technique the individual under test wears headphones and indicates perception of sound by pressing a response button. Modern devices can now employ computer generated algorithms and some forms of audiometry are essentially automated for use in an occupational setting (the so-called self-recording or Békésy type testing). Audiometric screening in the workplace became an important component in the early detection and indeed prevention of NIHL and is used regularly to current times. It is important to point out that audiometry of this nature is entirely subjective and relies on responses given by the individual under test. Over the years, largely under the auspices of the British Society of Audiology, robust standards have been set down for the carrying out of this procedure and with various British Standards in force. These pertain to the calibration of the audiometer, the type of headphones in use and most importantly ambient noise levels in which circumstances the test can be performed, that is these should be very low and very often testing takes place in a dedicated soundproof room or with the individual under test in a soundproof booth.

Various examples of pure tone audiometry are given in Figure 2 including that showing normal hearing and indeed showing the pattern of NIHL which represents high frequency sensorineural deafness and where in its typical form there is an audiometric notch at 4 kHz and bilaterally so. This is the typical audiometric hallmark of NIHL.

[9] Macfarlan D. History of Audiometry. *Archives of Otolaryngology*. 1939; 29(3): 514-519.



(a)



(b)

Figure 2. Pure tone audiograms showing (a) normal hearing (b) typical noise induced hearing loss. Units on the y axis are decibels (dB) adjusted so that zero represents the normal level heard by a young healthy individual, known as the International Organisation for Standardisation (ISO) level. Authors' collection.

Examples of the automated self-recording or Békésy audiometry that became used from the 1960s to the present time is as given in Figure 3 where a trace is produced on pre-prepared graph paper and where the zig-zag configurations arise as a result of the responses given by the individuals under test. The advent of this type of pure tone audiometry was an important advance in the detection and prevention of noise deafness in the formation of dedicated occupational screening programmes and by definition did not need to be performed by skilled personnel.

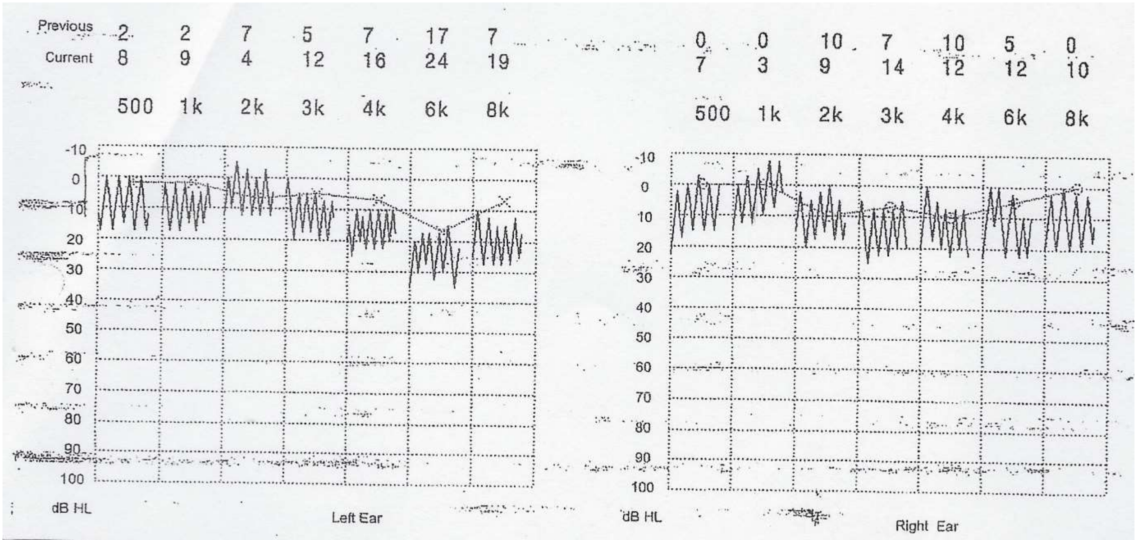


Figure 3. Self-recording (Békésy) audiometry used in an occupational setting. The thresholds of hearing are obtained from the 'zig zag' tracings. Units on the y axis are decibels (dB) of hearing loss (HL), equivalent to the ISO standard shown in Figure 2. Authors' collection.

Diagnostic aspects

The diagnosis of NIHL therefore is embraced by a number of principles as set out in Table 1.

1. A credible history of noise exposure
2. A demonstrable hearing loss that is material, that is capable of causing disability
3. The presence of diagnostic indicators (typically notching at 4 kHz) in the presence of high frequency hearing loss on pure tone audiometry
4. Absence of or consideration of confounding diagnoses, for example the effects of head injury

Table 1. Principles underlying the diagnosis of noise induced hearing loss. Authors' own work.

The credible history of noise exposure is of course an essential and important component in the diagnosis of NIHL. Clearly if this is not present, regardless of any clinical examination or audiometric findings, NIHL by definition should not exist. Whether or not an individual under investigation has been exposed to noise is ultimately not a matter for the clinician but for an acoustic engineer or occupational hygienist but it led to the concept of the so-called Noise Immission Level (NIL). This concept relies on what became known as the equal energy principle developed largely by Burns and Robinson, and led to the development of the National Physical Laboratory Tables.[10] [11] [12] As a result of this analysis and modelling the case was established that the higher the noise level over the longer time (and hence a higher NIL) the greater the likelihood of the production of noise deafness in a given population.[13] [14] Furthermore, these analyses enabled there to be a setting of what is known as the 'safe level' for exposure to noise in the workplace. Some authorities hold that there is no safe level of exposure as with asbestos and that all noise at whatever intensity has the potential to cause inner ear damage. However, it is generally contended that noise levels below 85 A-weighted decibels (dBA), a measure of the relative loudness of sounds perceived by the human ear) over an eight-hour working shift will not produce significant injury to the inner ear. This threshold is known as the Lepd (or 8-hour Leq).[15] Most recently as a result of European legislation this has been reduced to 80 dBA.

NIHL tends to be present in those with a longer history of exposure and where the inevitable effects of advancing age produce additional hearing loss due to the deafness of ageing, known as presbyacusis. Part of the problem, therefore, in diagnosis and quantification is to distinguish noise deafness ostensibly due to age and this is particularly important in respect of any potential compensation claim made by an individual in the later years of their employment or post-cessation of employment. The seminal documentation which quantified presbyacusis was presented by MS Shipton and published by the National Physical Laboratory at Teddington, Middlesex.[16] This became the yardstick for determining hearing loss from ageing. There has been considerable controversy which has now run for well over 50 years in respect of how disability should be determined from a pure tone audiogram which is the only indicator in common clinical practice whereby there is any quantification of actual hearing ability. A general consensus is that disability should be determined from hearing thresholds at frequencies of 1, 2 and 3 kHz.[17]

Now nearly 30 years ago, the Medical Research Council commissioned a study which became known as 'Hearing in Adults'.[18] This found that individuals of a given

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[10] Burns W, Robinson DW. *Hearing and Noise in Industry*. London: HMSO; 1970.

[11] Robinson DW (Ed). *Occupational Hearing Loss*. London: Academic Press; 1971.

[12] Robinson DW, Shipton MS. *Tables for the Estimation of Noise-Induced Hearing Loss. Acoustics Report AC61*. London: National Physical Laboratory; 1977.

[13] Robinson, Shipton, Tables, 1977 (Note 12).

[14] Anon. *Clinical Audiology Course Manual*. Institute of Sound and Vibration Research: University of Southampton; 1985.

[15] Coles RRA, Lutman ME, Buffin JT. Guidelines on the Diagnosis of Noise Induced Hearing Loss for Medicolegal Purposes. *Clinical Otolaryngology & Allied Sciences*. 2000; 25(4): 264-273.

[16] Shipton MS. *Tables relating pure tone audiometric threshold to age. Acoustics Report AC94.* London: National Physical Laboratory; 1979.

[17] King PF, Coles RRA, Lutman ME, Robinson DW. *Assessment of Hearing Disability Guidelines for Medico/Legal Practice*. London: Whurr Publishers; 1992.

[18] Davis A. *Hearing in Adults: The Prevalance and Distribution of Hearing Impairment and Reported Hearing Disability in the MRC Institute of Hearing Research's National Study of Hearing.* London: Whurr; 1995.

age were deafer than hitherto expected and so various corrections were introduced into the presbyacutic determinations from earlier sources, namely International Standard ISO 7029 (1984) which became modified in later years and most recently in a 2017 revision. One diagnostic conundrum for the practising clinician was the treatment of a pure tone audiogram which did not contain the textbook typical 4 kHz notch referred to above which is inevitably obliterated by the effects of ageing. The absence of this 4 kHz notch therefore does not preclude the presence of at least some degree of NIHL especially in the older subject. Resolution of this diagnostic difficulty was achieved by Ross Coles (1927-2017), Mark Lutman and Terence Buffin (1930-2015) in the seminal publication 'Guidelines on the Diagnosis of Noise Induced Hearing Loss for Medicolegal Purposes'.[19] In this publication, the authors developed the concept of an audiometric 'bulge'. When this feature is present there is increased deafness at noise sensitive frequencies principally 3, 4 and 6 kHz over and above that considered to be arising from age-related thresholds hypothetically generated from that expected for presbyacusis following application of 'misfits' at the anchor point frequencies of 1 and 8 kHz (Figure 4).

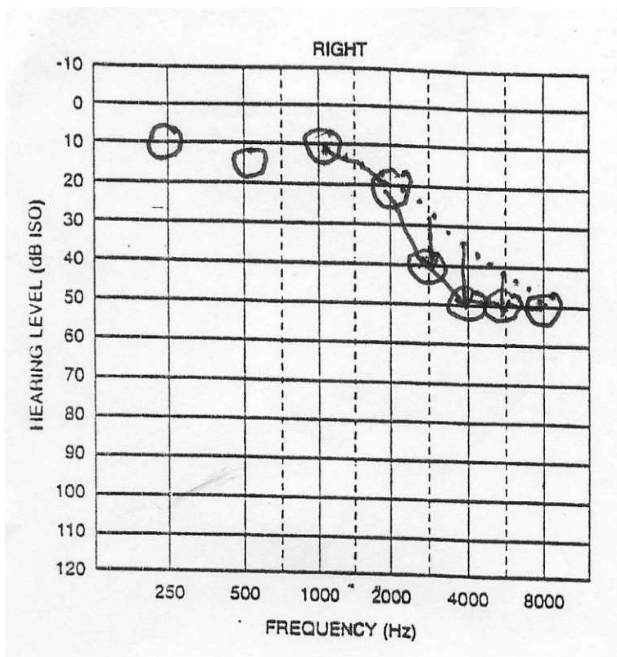

Figure 4. The audiometric 'bulge', an indicator of NIHL when a notch is not present. The circles represent the thresholds of hearing at various frequencies and the dotted line is the derived age-related values. Authors' collection.

This was a significant advance in the opinion of most authorities which enabled a formal and rigorous analysis of a non-notched audiogram in the investigation for the presence or indeed absence of NIHL. This paper further set out that there should be sufficient exposure to excessive noise but went on to quantify the exposure in detail,

[19] Coles *et al*., Guidelines, 2000 (Note 15).

that is stipulate the requirement of a NIL generally at or above 100 dB (although in some circumstances this can be lowered) derived from noise exposure at or above 85 dBA Lepd. This paper, however, only enabled the clinician to determine the presence or absence of NIHL on the balance of probability but not quantify it.

The same authors refined these concepts further to quantify NIHL using a previously described mathematical model presented by Willy Passchier-Vermeer dating from 1974.[20] From this they determine the quantum of noise deafness at 1, 2 and 3 kHz from the size of the audiometric bulge developed previously but where 'anchor points' at 1 and 8 kHz are effectively 'reset' to take into account any noise damage at these index frequencies.[21] Coming to more recent times these concepts were thus developed for the diagnosis of NIHL not only on the balance of probability but with a method for quantification, these aspects being particularly important with the ensuing proliferation of compensation claims for NIHL (with or without tinnitus) that the relevant legislation produced.

Historical aspects of the prevention of noise induced hearing loss

Common sense dictates that if an individual is not exposed to noise, or indeed that of an excessive nature, then NIHL will not develop. In the workplace and particularly in respect of certain manufacturing process this can in fact be difficult to achieve. The logical standpoint is to reduce the levels of noise to which an individual is exposed or if this is unavoidable to reduce the amount of time in a given working day to that part of the manufacturing process thus reducing the equivalent noise over a working shift to a level which is safe. The use of 'job rotation' as a means to limiting exposure with or without the use of acoustic 'refuges' is one that came to be used in industry to limit noise exposure but where, because of the logarithmic nature of the decibel, each halving of exposure time will only provide the equivalent of a 3 dB noise reduction.

The prudent employer will therefore have determined ambient noise levels to which its workforce is exposed usually by having a noise survey performed by an acoustic engineer and then with implementation of a hearing conservation programme after the identification of any acoustic hazards. This field of acoustic engineering developed largely in the 1960s as a result of reliable noise-intensity measuring devices which became capable of integrating or averaging sound levels and the monitoring of the noise dose by use of a body-worn device.[22] In the 1970s, areas with excessive noise became designated as noise hazard zones with an employer having requirement to display appropriate signage indicating this and that hearing protection must be worn. The engineering aspects of noise control and how this developed over the years remain a specialised area outside clinical practice but, for example, some engineering processes became enclosed or partitioned to screen or reduce noise levels presented to those

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[20] Passchier-Vermeer W. Hearing loss due to continuous exposure to steady-state broad-band noise. *Journal of the Acoustical Society of America*. 1974; 56(5): 1585-93.

[21] Lutman ME, Coles RRA, Buffin JT. Guidelines for quantification of noise-induced hearing loss in a medicolegal context. *Clinical Otolaryngology*. 2016; 41(4): 347-357.

[22] Health and Safety Executive. *Code of Practice for Reducing the Exposure of Employed Persons to Noise*. London: HMSO; 1972.

working in adjacent regions in the workplace environment. As is often the case, these control measures were not always possible or practical and an employer would have had regard to various cost issues.

When these engineering aspects cannot be easily addressed then personal ear protection is used. Historically these have taken the form of simple cotton wool (Bilsom wool) but latterly disposable plastic foam earplugs, those prefabricated to the individual, personally moulded ear inserts or specially manufactured ear muffs on a headset which can fitted onto a safety helmet. The advent of these devices largely from the 1960s as a result of *Noise and the Worker* (1963) established this year as the date of so-called 'Guilty Knowledge'.[23] This became relevant following claims for compensation for NIHL (see below) although in the 1950s some fortunate miners and steelworkers were given ear protection by particularly prudent employers (even though they were not legally at that stage required to do so) and this also applied to some branches of the Armed Forces.

In association with ear protection was a general sense of improving health and safety issues which became part of the culture moving through the 1980s, 1990s and into the present century. This was associated with education of the workforce as part of any hearing conservation programme particularly involving unionisation of the workforce and with regular health and safety workplace committee meetings. Indeed, the Noise at Work Regulations (1989) became a yardstick for industrial and commercial practice in this respect. The use of surveillance audiometry in the workplace became highly developed in recent times including a pre-employment test not only to eliminate or detect the earliest features of noise deafness but also to protect the employer from potential compensation claims from those who had a pre-existing hearing loss present. This is particularly relevant in those susceptible to developing NIHL and where it is essential that such an individual should not be exposed further to potentially injurious noise levels.

Historical aspects of relevant legislation

Noise and the Worker (1963), as discussed above, established the date of 'Guilty Knowledge' from which employers were expected to be aware of the potentially injurious nature of noise exposure to their workforce in most occupations and with provision of the various measures detailed above including, for example, freely available and regularly maintained hearing protection. The Health and Safety at Work Acts in various forms, and particularly that from 1974, place duties on an employer as far as is reasonably practicable to show responsibility for aspects of health, safety and welfare at work to all its employees but not specifically in respect of noise exposure. Around 1983 the Factory Inspectorate began to issue improvement notices requiring monitoring and reduction of noise levels and with prohibition notices where risk of serious personal injury is a potential outcome. Statutory compensation became available for occupationally acquired NIHL in some case under the provisions of the National

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[23] Department of Employment. *Noise and the Worker. Health and Safety at Work Booklet No 25.* London: HMSO; 1963.

Insurance (Industrial Injuries Act). This was set out in several Statutory Instruments identifying NIHL as a prescribed disease. This statute applied to those employed at any time since 1948 for a period of ten years or more in one or more of the prescribed occupations which need not have been continuous in nature but where the claim generally must have been made within five years of the date of last employment in any of these. This included those using pneumatic percussive or high-speed grinding tools, for example fettling, shipbuilding or repairing, quarrying/drilling rock, and also included those employed in drop forging, weaving, cutting, shaping or cleaning metal and various woodworking equipment including chainsaws. The hurdle for securing such compensation which is pensionable is high, that is the applicant has to be very deaf and showing that they have significant sensorineural hearing loss amounting to at least 50 dB in each ear averaged at 1, 2 and 3 kHz which represents significant hearing loss. The practice was to attribute a percentage disablement to each increase in hearing loss over 50 dB with 20% being given for 50-52 dB and 100% to those with average hearing losses in excess of 88 dB. In this Department of Health and Social Services scheme the concept of binaural disability was developed which is still in use today, that is where the hearing impairment/disability is weighted 4:1 in favour of a better hearing ear.

This high hurdle involved in obtaining statutory compensation was in complete contrast to that obtained through common law in respect of compensation for personal injury of which NIHL (and tinnitus) form part. In these cases the Court will take the standard as that of a reasonable and prudent employer and what they ought to have known as in *Stokes v Guest, Keen and Nettlefold (Bolts and Nuts) Ltd* [1968]. The early actions produced inconsistent judgments although a precedent was established in 1971 in *Berry v Stone Manganese and Marine Ltd* [1972] where judgment was given in favour of the claimant. The Court found that significant and negligent noise exposure had occurred over a period of years in addition to where the claimant was able to prove that the employer had been negligent. Although hearing protection was provided at some stage, the choice and whether or not use was indicated was left to the employee without any supervision and/or training and where the claimant stated that had they known this they would have been worn when applicable.

There were, however, other cases around this time in contrast to this where the defendant obtained the judgment and the claimants were not successful in obtaining compensation, for example *McIntyre v Doulton & Co. Ltd.* (unreported, 1978) and *McGuinness v Kirkstall Forge Engineering Co. Ltd.* (unreported, 1979). Both of these cases turned on causation, that is the establishment of NIHL in each claimant on the balance of probability and which were not successful but other cases followed in the late 1970s and 1980s which set the ground rules for subsequent legal actions, for example *Thompson v Smiths Shiprepairers (North Shields) Ltd.* [1984], *Blacklock and another v Swan Hunter Shipbuilders* [1981], *Mitchell v Vickers Armstrong Ltd. and another* [1982] all of which were heard in the industrial settings of the North East. These cases set out principles of apportionment of damages which again became applicable in the trial of subsequent actions to the present time. In these early cases the Ministry of Labour booklet *Noise and the Worker* (1963) was judged to be the benchmark from which the date of knowledge was obtained. These claims at common law continue to the present time albeit in reduced numbers because industry has generally become less noisy, more automated and with a reduced workforce. In addition, the not inconsiderable greater use of Personal Protective Equipment including hearing protection and so the actual incidence of NIHL (and tinnitus) in the population has become very much less. Even if present it has often not arisen as a result of the negligence of an employer but frequently from other noise such as that sustained socially in the course of hobbies including recreational shooting.

The Department of Employment's *Code of Practice (Code of Practice for Reducing the Exposure of Employed Persons to Noise*, 1972) specified a limit for noise exposure and detailed steps to be taken in the workplace to limit noise exposure including signposting of areas where ear protection was required, the control of entry into designated noise zones, the provision of suitable hearing protection with enforcement of its use and instruction of the workforce in the care and usage of such ear protection.[24] Furthermore, in Section 4 of this publication exposure to excessive noise was given as should not be in excess of 90 dB(A) Lepd, that is over an eight-hour working shift. This *Code of Practice* set out what was known as action levels as set out in Table 2.

First Action Level (85 dBA Lepd)
• Workplace noise levels to be assessed by trained personnel and a record of this to be kept
• Employees to be informed of risks of hearing and on request be provided with suitable and appropriate ear protection
Second Action Level (90 dBA Lepd) and Peak Action Level (200 Pa, 140 dBC)
• All of the above in addition to: Suitable and efficient ear protectors to be provided and used by all workforce so exposed
• Exposure of employees to noise to be reduced as far as is reasonably practicable by means other than ear protection
• Ear protection zones to be identified and signposted

Table 2. Summary of the Department of Employment's *Code of Practice* published in 1972.[24]

This was further refined in the Control of Noise at Work Regulations (The Noise at Work Regulations 2005 Statutory Instrument 2005 Number 1643). This was based on European legislation, that is Council and Parliament Directive 2003/10/Ed of 6 February 2003 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise) 'which came into force on 6 April 2006 with exceptions for the music industry and seagoing employment'. The main difference

[24] Department of Employment. *Code of Practice for Reducing the Exposure of Employed Persons to Noise*. London: HMSO; 1972.

with the 1989 noise regulations previously enforced (the Noise at Work Regulations 1989 Statutory Instrument 1989 Number 1790) are given as the two action values for daily noise exposure have been reduced by 5 dB(A) to 85 dB(A) and 80 dB(A), two action levels or peak noise at 135 dB(C) and 137 dB(C) were introduced along with new exposure limit values of 87 dB(A) (daily exposure) and 140 dB (peak noise) which take into account the effect of hearing protection and which must not be exceeded.

Thus the legislation developed along the lines of increasing awareness of the adverse effect on hearing from noise exposure with a progressive reduction in the noise levels to which employees could be exposed.

Rehabilitation of those with noise-induced hearing loss

Sensorineural hearing loss is not amenable to medical or surgical treatment and this has been widely accepted from the start. Prior to the development of the thermionic valve, amplification of sound was not possible other than with the use of a hearing trumpet and in the past remarkable ingenuity has been shown to disguise these, for example by incorporation into the bouffant hairstyle of women. Sound amplification from the 1920s onwards with the development of the triode valve by Lee de Forest provided an important breakthrough and indeed towards the end of the 1940s into the 1950s there was the development of miniature devices which provided enough amplification to be useful. With some of these earlier aids the high- and low-tension batteries required were often larger than the devices themselves, all of which were body worn.

In the 1960s with the advent of solid-state circuitry (the transistor and latterly integrated circuits) miniaturisation of hearing aids has proceeded further at a dramatic pace with the establishment of the BE (Behind Ear) series of aiding obtained through the NHS which were post-aural, ear level devices which were less obtrusive but nevertheless visible. Mobile phone signal processing technology has enabled vast advances to be made particularly in respect of listening to speech in background noise, which is difficult for those with sensorineural hearing loss, and also miniaturisation where the aid in some circumstances can actually be hidden in the ear canal itself and hence not visible to the casual observer.

Conclusions

NIHL is a common occupational condition that has occurred in those working in a wide range of roles and industries. The definition and accurate diagnosis of NIHL has incorporated medical, technical and legal aspects. Repercussions for employers have driven greater awareness of the condition and measures to prevent it. Thankfully, after historically high prevalence, occupational NIHL is finally decreasing in incidence.

Biographical Details

Mr Andrew J Parker LLM DLO ChM FRCS is a Consultant Ear, Nose & Throat Surgeon who worked in the NHS for 35 years and is now based at Peak Medical Practice in Derbyshire. He has undertaken medicolegal work in the field of occupational deafness for the last 25 years and is a member of the Aesculapian Society of Sheffield.

Dr Josephine H E Parker BVMS MRCVS is an Advanced Practitioner in Veterinary Ophthalmology at The Royal (Dick) School of Veterinary Studies, University of Edinburgh. She has a keen amateur interest in the history of science, medicine and veterinary practice.

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