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Occupational Noise Induced Hearing Loss and Audiometry

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Summary

Noise-induced hearing loss (NIHL) affects approximately five percent of the population worldwide (Zhou et al., 2013), making it a global public health concern. Occupational NIHL (ONIHL) occurs from continuous exposure to excessive noise, usually over a number of years. Continuous or intermittent noise in the work environment exceeding 85dB(A) during an eight-hour shift, or impact noise exceeding 120dB(A) during an eight hour working shift, is considered hazardous. Noise-induced hearing loss (HL) resulting from exposure to excessive occupational noise is a substantial health burden, and one of the most common chronic occupational diseases. In Australia, between July 2002 and June 2007, there were approximately 16,500 occupational NIHL workers compensation claims.

Exposure to excessive noise can cause permanent damage to auditory structures; resulting in permanent threshold shifts that ultimately cause hearing damage. Noise induced hearing loss is a sensorineural (SNHL) hearing loss categorised by a high frequency 3-6 kHz notching audiometric pattern. Damage resulting from noise exposure usually begins at 3-6 kHz (Ali, Morgan, & Ali, 2014). However, with continued noise exposure, damage can spread to both lower (2, 1 kHz) and higher frequencies (8 kHz; Ali, (Morgan, & Ali, 2014). With prolonged or severe exposure damage can occur at frequencies as low as 0.5 kHz (Ali, Morgan, & Ali, 2014). However, NIHL typically affects audiometric thresholds at 4 and 6 kHZ (Moore, 2016). Pure tone audiometry (PTA) is considered the 'gold standard' for measuring SNHL (Chau, Cho, & Fritz, 2012; Dillion, Beach, Seymour, Carter, & Golding, 2016; Fredriksson, Hammar, Magnusson, Kahari, & Waye, 2016). However, PTA is unable to detect early hearing loss (Venet, Campo, Rumeau, Thomas, & Parietti-Winkler, 2014). Thus, additional audiometric tools are required to screen for sub-clinical hearing disorder.

Improved protective measures and reduced exposure to excessive noise, particularly in the Western world, has reduced the impact of ONILH. Yet, ONIHL remains one of the most reported occupational diseases worldwide. This may partially be due to a lack of effective screening protocols designed to detect early ONIHL. As the effects of noise exposure are permanent and additive, early detection is vital to protect against preventable HL, such as ONIHL.

Occupational NIHL is a financial burden on both employers and employees. Due to the medical, social, and economic repercussions of ONIHL, early detection and treatment is paramount. Thus, it is important to identifying people who are at greater risk for ONIHL, and target screening and educational programs that promote hearing protection and safety measures in the industries where people are most at risk. In Australia, the construction industry, transport industry, and Defence are prominently affected by ONIHL. However, there is also a considerable risk of ONIHL for professional orchestras and some health care workers. Through targeting hearing prevention programs to these industries, 'best practices' in hearing loss prevention can be promoted, and the outcomes of the programs can be measured.

In addition to the financial costs associated with ONIHL, there are also personal costs to those whose hearing has been impaired. The ability to understand speech can be impeded by NIHL for frequencies above 3 kHz (Moore, 2016). This becomes even more difficult when there is background noise (Moore, 2016). As a result, people with NIHL can be less inclined to socialise and can often become isolated. This can lead to increases in depression and anxiety. Exposure to excessive noise can also cause auditory fatigue and affect memory and decision-making. Occupational NIHL can also result in a loss of employment, due to safety restrictions or a reduced capacity to communicate. The inability to continue working can result in personal economic hardship for people impacted by ONIHL. However, the use of Hearing Protection Devices (HPDs) can help to bolster occupational and social functioning.

However, an Australian study indicated that exaggeration of hearing loss is estimated in approximately 17% of ONIHL cases (Rickards & De Vidi, 1995). Conversely, workers have also been found to under report hearing loss risk factors and functional hearing status on screening surveys (Mosites et al., 2016).

Thus, reliable tools for assessing HL are essential for identifying and treating ONIHL. Screening and assessment tools that can be used with uncooperative workers, as well as differentiate potential feigning or malingering from legitimate cases of ONIHL in workers compensation cases need to be included in the battery of audiological testing when screening for ONIHL.

There is a need for early diagnosis of subclinical HL through screening and effective treatment and management of ONIHL. This is an update of an earlier report (Schaafsma, Benke, Radi, & Sim, 2010) on ONIHL research prior to 2010. This report will consider recent research on ONIHL from 2010 to date, and also describe the best practice diagnosis, treatment, and outcome measures of ONIHL.

Acronyms and Abbreviations

CI	cochlear implant
ENT	ear, noise, and throat doctor
HAs	hearing aids
HL	hearing loss
HPDs	hearing protection devices
NAL	National Acoustic Laboratories tables
NIHL	noise-induced hearing loss
ONIHL	occupational noise-induced hearing loss
PTA	pure tone audiometry
SNHL	sensorineural hearing loss

Clinical summary

ONIHL Diagnosis

Pure tone audiometry is the 'gold standard' of audiometric screening to assess NIHL (Chau, Cho, & Fritz, 2012; Dillion et al., 2016; Fredriksson et al., 2016). Highly trained clinicians are required to perform PTA in sound-attenuating facilities, which can be costly and time consuming. While, conventional PTA is able to differentiate between the four main types of HL, sub-clinical hearing impairment may not be detected with PTA. Additional tests including otoacoustic emissions tests and auditory steady state responses can be used to detect sub-clinical hearing damage. Additional tests can also be used to assess everyday functioning and communication. Speech-in-noise tests are efficient and reliable for this purpose. Furthermore, PTA is open to manipulation by people who attempt to feign hearing loss (Rickards & De Vidi, 1995). Additional testing may be required in these cases.

Differentiating between NIHL and HL that can be attributed to age is amongst the most common difficulties in diagnosing NIHL. However, the identification of a high frequency 3-6 kHz notching audiometric pattern can help rule out age related HL (Ali, Morgan, & Ali, 2014; Kirchner et al., 2012). Additionally, an age correction can be applied to account for the effect of age on HL.

Otolaryngologists and audiologists must ultimately make subjective clinical judgments regarding when hearing impairment is more likely than not due to occupational noise. When doing this they should assess workers noise exposure history and also take into account confounding factors (e.g., gender, age, and race) as well as risk factors (e.g., smoking, recreational noise exposure, medical history, tinnitus, and use of medications; Cunningham & Tucci, 2017; Kirchner et al., 2012).

ONIHL Treatment

While the current treatment is amplification with the use of HPDs (Giordano et al., 2008), it is recommended that best practice treatment for the management of ONIHL encompass both HPDs and audiological rehabilitation. While conventional hearing aids (HAs) are the most common from of HPD used to treat NIHL, semi-implantable middle ear devices (e.g., cochlear implants [CIs]) may be more suitable in rare cases (profound bilateral SNHL). This will depend on a person's candidacy for CIs as well as the communication results that can be achieved with conventional HAs.

ONIHL Outcome

Hearing prevention programs should include screening for early indications of ONIHL. This may help detect people who have sub-clinical HL and are at risk for developing NIHL. Prevention of ONIHL is preferable over treatment. Treatment outcomes can be measured in relation to workers hearing ability with the use of HPDs, communication ability after rehabilitation, and overall satisfaction with the treatment and management of their HL. Workers level of functioning with the use of HPDs can be assessed through a follow-up audiological assessment to evaluate treatment outcomes.

Contents

Rapid review: research questions

This review will address the following questions:

Diagnosis

1. What is the best practice diagnosis for noise induced hearing loss?
2. Is it possible to differentiate noise induced hearing loss from other types of hearing loss?
3. Who can do the test and interpret the results (who is making the assessment)?
4. Who should make the diagnosis for noise induced hearing loss?
5. Is this informed by evidence or scope of practice?

Treatment

1. What is the best practice treatment for noise induced hearing loss?
2. What are the clinical indications for determining the type and cost of hearing aid that is prescribed?

Outcomes

1. How should SIRA measure the outcomes for noise induced hearing loss claims?

Diagnosis

Best Practice Diagnosis For Noise Induced Hearing Loss

In medico-legal investigations, ONIHL is primarily assessed using PTA (Chau et al., 2012; Dillion et al., 2016; Fredriksson et al., 2016). Pure-tone audiometry is still considered to be the 'gold standard' of audiometry for determining type and degree of HL (Chau et al., 2012; Dillion et al., 2016; Fredriksson et al., 2016). When screening large occupational populations, more cost effective and time efficient tests can be performed to identify people who are in need of more conventional testing (i.e., PTA). Additionally, otoacoustic emissions tests can be used to screen for sub-clinical NIHL. Currently, this measure is not commonly included when screening for ONIHL. Yet, the inclusion of otoacoustic emissions tests in an audiometry test battery could help identify workers who are at risk of developing ONIHL.

Audiological Diagnostic Assessment

Identify whether hearing or auditory-related impairment is present:

- Otoscopy
- Audiometry test battery
    - PTA
    - Otoacoustic emissions tests (screening for sub-clinical hearing loss)
    - Speech-in-noise test (assess real world functioning - communication)

Determine whether the hearing impairment is a result of excessive noise exposure:

- Detailed case history (e.g., history of exposure to hazardous noise, ontological infections or disease, otoscopic abnormalities)
- Risk factors (e.g., tinnitus, diabetes, smoking, medications)
- Confounding factors (e.g., age, gender)

Determine the impact of the hearing impairment on the client:

- Communication skills
- Social functioning

Develop a treatment / management plan:

- Select and fit a HPD
- Assess whether auditory rehabilitation / counselling is required
- Monitor the impact of the HPD and rehabilitation on communication
- Rehabilitation or HPD may not be desired

Pure Tone Audiometry

In occupational medicine, hearing screening is primarily based on PTA (Chau et al., 2012; Dillion et al., 2016; Fredriksson et al., 2016). This test has been found to produce accurate thresholds and assess the integrated functioning of the components of the auditory system. Conventional PTA is conducted in a soundproof room using a well-calibrated, high-quality audiometer. A well-trained administrator is required to administer the test. Due to this, large-scale screening is often time consuming and expensive.

Conventional PTA involves air-conduction, pure-tone hearing thresholds and can measure octave intervals from 0.25 to 8 kHz. The test-retest variability of pure tone thresholds at 6 and 8 kHz is poorer than at other frequencies, with 8 kHz slightly worse than 6 kHz (Flamme et al., 2014). Six kHz is a key frequency for the early detection of NIHL, however, poor test-retest reliability in significant threshold shifts at 6 kHz has been a problem in hearing-conservation programs (Lapsley-Miller, Reed, Robinson, & Perez, 2018). The ability to reliably identify smaller significant threshold shifts would allow for the detection of sub-clinical HL. Thus, additional testing is required in order to identify early signs of mild HL.

Screening of this nature could help to protect against ONHIL by identifying people who are at risk of developing NIHL.

Recent findings have indicated that PTA with the use of insert earphones (especially with coupler calibration) is more reliable than with supra-aural headphones (Lapsley-Miller et al., 2018). Due to sensitivity to standing waves, the coupler calibration is recommended over the in-the-ear SPL calibration. This improved reliability could help to identify significant threshold shifts at 6kHz, and the assist with the early detection of NIHL.

While PTA remains the 'gold standard' for assessing NIHL, it is also resource and time intensive. Thus, for mass hearing screening in large occupational settings, alternative testing that is reliable and efficient is needed to identify workers with hearing problems who may need further testing, as well as workers with early signs of HL who may be at risk of developing NIHL.

Hearing Thresholds

An anchor point of 1 and 8 kHz is the standard recommendation for a medical diagnosis of NIHL (Ali, Morgan, & Ali, 2014). However, some studies have suggested that the use of 1 and 8 kHz anchor points cannot be reliably substantiated and may, therefore, be unreasonable for estimating NIHL in all cases (Ali et al., 2014). Due to this, other diagnostic tools that can be used to support a diagnosis of NIHL are required.

Hearing thresholds can be compared with national or international standards in order to assess ONIHL. However, it is important that the control data used for such comparisons is based on people who do not differ from noise-exposed workers in important ways. People who are subjected to excessive occupational noise are more likely to have diabetes, be poorly education, be exposed to excessive non-occupational noise (e.g., loud music), and smoke (Dobie & Agrawal, 2011). These factors have also been found to contribute to hearing disorder.

Physicians must assess the probability that HL is largely due to confounding (e.g., gender, age) or risk factors (e.g., diabetes, smoking, anti-depressant medication) and not a direct result of ONIHL. The international standard on NIHL (ISO-1999) Annexes can aid clinicians to assess the contribution of confounding factors on HL when considering a diagnosis of NIHL (e.g., Guest, Boggess, & Attia, 2012). ISO-1999 offers Annex A, B, and C for comparison. Annex A outlines the distributions of hearing thresholds for people of specific ages, and makes exclusions based on ear disease, otoscopic abnormalities, and noise exposure. Annex B outlines the distributions of hearing thresholds from an unscreened population (US population 1959-1962). Annex C outlines the distributions of hearing thresholds for people without occupational noise-exposure. Ultimately, ISO 1999 data can be used to estimate the expected contribution of a worker's age and sex to HL. This enables clinicians to account for these confounding factors when trying to determine whether NIHL is primarily work related (e.g., Dobie, 2015). The net effect of factors including age, gender, noise exposure level, and noise exposure duration need to be considered. However, audiometric thresholds at 4, 6, and 8 kHz should still be taken into account when assessing ONIHL in a medico-legal context (Moore, 2016). It is understood that this is done in audiometric assessment in NSW.

Audiometric Notches

Occupational NIHL is characterized by bilateral symmetric SNHL, with a typical notch on PTA over 3, 4, or 6 kHz (Kirchner et al., 2012). However, ONIHL cannot be determined solely on the presence of bilateral audiometric notches (Hsu, Wu, Chang, Lee, & Hsu, 2013), as not everyone who is exposed to excessive noise will present with audiometric notches.

Summary of the Typical Presentation of Noise-Induced Hearing Loss

While individuals can deviate from these presentations, the following symptoms are consistent with NIHL:

- Typically bilateral
- A loss that is mild in lower frequencies and severe in higher frequencies
- NIHL decelerates over time (age related HL accelerates)
- Risk of NIHL rises with exposure levels (daily exposures above 85dBA)
- Temporary threshold shifts typically precede permanent threshold shifts
- Early notching at 3, 4, or 6 kHz (ARHL typically lacks notching)
- Presence of 4 kHz audiometric notch
  - Flat
  - Upward sloping
  - Severe to profound loss (especially in workers < 50 years old)
  - Extremely variable thresholds
  - Large differences between ears

Early Screening and Detection of Hearing Loss

Additional diagnostic tests are needed to monitor damage caused by occupational noise exposure in order to detect hearing changes and mild sub-clinical signs of hearing disorder not yet detectable using conventional PTA. Early detection of ONIHL is paramount for identifying workers in need of intervention and preventing further hearing damage.

Otoacoustic Emissions Tests (OAEs)

Two studies that compared otoacoustic emissions tests with PTA for assessing NIHL were reviewed. Both studies found distortion product otoacoustic emissions to have an increased sensitivity and determined that they are, therefore, better able to detect mild NIHL in comparison to PTA (Boger, Sampaio, & de Oliveira, 2012; Hellman, Jansen, & Dreschler, 2010). Thus, DPOAEs can be used to assess pre-clinical damage and monitor susceptibility to NIHL. However, most studies of DPOAEs are based on group results (Boger et al., 2012; Hellman et al., 2010), and an investigation of individual changes has shown that they do not always follow the same pattern as overall group-averaged effects (Helleman & Dreschler, 2012).

One study that compared contralateral acoustic stimulus distortion product otoacoustic emissions with PTA for assessing NIHL indicated that measuring efferent reflexes thresholds using contralateral acoustic stimulation would be valuable in early diagnosis of ONIHL, as well as identifying groups of noise-exposed workers who are most at risk of developing ONIHL (Venet et al., 2014).

In summary:

Distortion Product Otoacoustic Emissions (DPOAEs)

- Reveal the functioning of the outer hair cells
- More sensitive to effects of noise in the auditory system than PTA
- Quick and non-invasive
- Objective and accurate

Contralateral Acoustic Stimulus Distortion Product Otoacoustic Emissions (CAS DPOAEs)

- Test the inner / outer hair cells and ER
- Can be performed with non-cooperative workers

- Quick and non-invasive
- Can be performed in any quiet room

Auditory Steady State Responses (ASSRs)

Two studies that compared auditory steady state responses with PTA for assessing NIHL were reviewed. The auditory steady state responses technique is primarily geared towards early identification of people who are at risk of developing NIHL, as it has a high sensitivity to predicting hearing thresholds and moderate to severe HL (Attias, Karawani, Shemesh, & Nageris, 2014). Auditory steady state responses is also useful as an initial approximation of the behavioural audiogram in cases where an individual is non-cooperative or may be feigning in an attempt to qualify for compensation (Attias et al., 2014; Karawani, Attias, Shemesh, & Nageris, 2015). It is recommended that the use of auditory steady state responses be combined with other auditory tools (i.e., otoacoustic emissions testing; Attias et al., 2014; Karawani et al., 2015).

Quasi Auditory Steady-State Response (QASSR)

Two dissimilar stimulation techniques, transient and steady-state, are combined to form the quasi auditory steady-state response method, which is a stimulation-analysis paradigm that predicts behavioural thresholds in people with SNHL (Lachowska, Bohorquez, Ozdamar, & Niemczyk, 2016). Quasi auditory steady-state response was created for practical clinical application, to provide additional information through the transient auditory brainstem response. This technique improves the overall performance of the electrophysiological threshold estimation (Lachowska et al., 2016). Simultaneous recordings of auditory steady state response and tone burst auditory brainstem response from quasi auditory steady-state response provides information about thresholds and transient tone burst auditory brainstem response waveforms at different carrier frequencies (Lachowska et al., 2016). Quasi auditory steady-state response informs on hearing status, and also displays a visual response corroboration of the data (Lachowska et al., 2016).

High-Frequency Audiomtery (HFA) and Extended High-Frequency Audiomtery (EHFA)

Three studies that compared high-frequency audiometry with PTA for assessing NIHL indicated that high-frequency audiometry and extended high-frequency audiomtery have high sensitivity and are, therefore, more geared towards detecting sub-clinical changes in hearing than conventional PTA (Ma et al., 2018; Mehrparvar, Mirmohammadi, Ghoreyshi, Mollasadeghi, &Loukzadeh, 2011; Riga, Korres, Balatsouras, & Korres, 2010). The number of years a worker has been exposed to occupational noise has been found to impact which frequencies are affected when there are signs of ONIHL (Riga et al., 2010). In a recent study of industrial workers, during the first 10 years of employment, frequencies 12500, 14000, and 16000 Hz were found to be the only ones affected (Riga et al., 2010). Between 11 and 20 years of employment, frequencies 2000 and 4000 Hz were significantly affected (Riga et al., 2010). In contrast, after 20 years of employment, frequencies 250, 500, and 1000 Hz were affected (Riga et al., 2010). This indicates that the early detection of hearing sensitivity to noise could help prevent HL in lower frequencies, especially speech frequencies.

Screening Questionnaires

Questionnaires that assess exposure to hazardous occupational noise can be used to assess the risk of developing ONIHL. A self-report questionnaire that assessed sound-induced auditory fatigue was found to have high sensitivity >85% (95% CIs 56 to 100%) and specificity >70% (95% CIs 55 to 84%) for indicating hearing disorder later diagnosed by otoacoustic emission or conventional audiometry (Fredriksson, Hammar, Magnusson, Kahari, & Waye, 2016). Seventy one percent of people who self-reported sound-induced auditory fatigue were then found to have HL diagnosed by optoacoustic emission testing (Fredriksson et al., 2016). The survey question asking about auditory fatigue identified almost 90% of people with hearing disorder diagnosed with PTA or distortion product otoacoustic emissions, and correctly dismissed 70% of people without a diagnosed hearing disorder (Fredriksson et al., 2016). These results indicate that questionnaires could be a cost efficient pre-screening tool to assess workers who are in need of further testing with conventional PTA.

Hearing conservation programs that incorporate questionnaires and regular screenings that utilise optoacoustic emission tests could be used to detect early changes in hearing status that occur before the onset of ONIHL. Alternatively, high-frequency audiomtery and extended high-frequency audiomtery can also be used for screening of sub-clinical hearing disorder. In instances when workers are non-cooperative, initial screening with otoacoustic emission tests, followed by auditory steady state response testing of frequencies that failed the otoacoustic emission tests could also be used.

When assessing workers case history, exposure to hazardous noise is traditionally gauged through self-report measures. However, this method is influenced by both reporting procedures and the ability of people to accurately recall their lifetime exposure to noise. Also, there may be instances where people may choose to over or under report their exposure to occupational or recreational noise. Instruments such as the Noise Exposure Structured Interview can be used to estimate noise exposure duration, sound level, and use of hearing protection for specific periods of a persons life (Guest et al., 2018). The use of structured instruments could potentially increase the accuracy of the amount of noise exposure that can be attributed to occupational noise. More research is needed to determine the value of structured interviews for use in determining workers noise exposure history.

Alternative Testing for Use in Large Occupational Populations

Automatic Audiometry

Automatic audiometry is a method of measuring hearing thresholds using a predetermined algorithm, rather than a clinician. Automatic audiometry using a combination of automatic PTA and a computerized tone-in-noise detection task has been shown to have significant test-retest results at all test frequencies (automatic audiometry: r=.97 to .99; p<.0001; TIN: r=.81 to .94; p<.0001; Convery et al., 2014). Correlation analysis of manual and automatic audiometric thresholds, performed as a measure of validity, have revealed a strong, significant correlation at all test frequencies (r=.98 to .99; p<.0001; Convery et al., 2014). As a result, automatic audiometry is suitable as an initial screening of ONIHL in large occupational settings. Self-fitting HAs, which are assembled, programmed, fine-tuned, and managed without the aid of a clinician necessitate an automatic audiometry test. For workers who decide to refuse professional treatment, automatic audiometry could help with the use of self-fitting HAs. Automatic audiometry is also a practical solution to screen large occupational populations, when conventional PTA conducted by clinicians may not be cost effective.

Mobile Wireless Automated Hearing-Test System (WAHTS)

The mobile wireless automated hearing-test system has users respond to pure-tones with an iPad. It is simple to understand and easy to operate, with user-friendly instructions (Meinke, Norris, Flynn, & Clavier, 2018). The ability of untrained operators to test workers in the workplace, without the use of sound-attenuating enclosures, means that the wireless automated hearing-test system can be implemented with minimal cost to large groups of workers. Recent research has substantiated the ability of the wireless automated hearing-test system to obtain valid hearing thresholds that are comparable to those obtained using conventional computer-automated audiometry (Meinke et al., 2018).

Large-scale industrial hearing conservation programs could benefit from automated diagnostic testing that does not require a clinician, and can be completed on site in environments that exceed the maximum permissible ambient noise levels required for conventional PTA. This can help to cut costs of audiometric screening. The aforementioned tests would be suitable for screening large occupational populations, however, follow up PTA would still be required to diagnose ONIHL, especially for workers compensation claims.

Speech-in-Noise Tests

Speech-in-noise hearing screening tests are self administered, automated tests that are delivered by telephone or over the Internet. Speech-in-noise tests can help to determine the everyday challenges of people with hearing loss; chiefly understanding conversation in background noise. Thus, they are used in clinical settings to: understand individual hearing disability; determine peoples ability to communicate and understand speech in the general environment where there is noise; manage peoples expectations; and implement and manage a tailored hearing intervention program for people with NIHL. A comprehensive diagnostic audiometric test battery encompassing both PTA and speech-in-noise testing would determine not just the type and degree of HL, but also the everyday functioning of people with ONIHL. This may help to inform on the specific features required in a HA that will support optimal hearing within the patients lifestyle (e.g., talking on the telephone, watching television, travelling in the care, talking one-on-one, talking in small or large groups).

Occupational Earcheck (OEC)

The Occupational Earcheck is a Dutch online self-screening speech-in-noise test that was developed for the detection of ONIHL. The improved Occupational Earcheck saw the addition of homogenisation of the speech material in a low-pass filtered noise, and was also shortened (Rashid, Leensen, de Laat, & Dreschler, 2017).

In summary for this technique:

- Suitable for detection of high-frequency HL among noise-exposed employees
- Good sensitivity and specificity
- Good discriminative power
- Possible learning effect
- Automatic conditional rescreening improved test specificity (93%; Rashid & Dreschler, 2018)
- More accurate screening test for higher degrees of NIHL (sensitivity 94% / specificity 90%; Rashid & Dreschler, 2018)

Earcheck

Earcheck is suitable for detecting NIHL. Diotic presentation mode (loudspeakers) yielded lower speech reception thresholds than a monotic presentation mode (headphones) with people who are hearing impaired (Leensen & Drechler, 2013a).

- Moderate sensitivity (68%)
- Good specificity (71%)
- High learning effect (reduced with increasing test number; (Leensen & Dreschler, 2013b)
- Headphones are recommended for domestic screening (Leensen & Drechler, 2013a).

Digits-in-Noise Test (DIN)

The Digits-in-Noise test is an automated self-screening speech-in-noise test.

- Developed for diagnostic and clinical purposes
- Support diagnostic hearing assessments

- Evaluate HA fittings
- Manage hearing expectations

The Digit Triplet Speech-in-Noise Test

The Digit Triplet Speech-in-Noise test is an automated self-screening speech-in-noise test administered by telephone.

- High sensitivity and specificity for detecting early signs of high-frequency hearing loss (90%; Jansen, Luts, Dejonckere, van Wieringen, & Wouters, 2013)
- Short test duration – approximately four minutes per ear
- Easy to use
- Identifies people who are likely to benefit from assistive technology (HPDs)
- Low measurement error
- Less influenced by non-auditory cognitive abilities
- Sensitive to the first signs of HL
- Useful for screening large populations

Differentiating Noise Induced Hearing Loss From Other Types of Hearing Loss

Audiometry is used to establish both the severity and type of HL. Conventional audiometric tests (PTA) are used to differentiate between the four principle categories of HL: SNHL; conductive hearing loss; mixed hearing loss; and functional hearing loss. In diagnosing NIHL, other causes for hearing loss need to be considered as differential diagnoses.

Functional Hearing Loss

When there is no detectable pathology in the auditory system and no hearing loss is detectable with audiology testing, HL is attributed to psychological or emotional problems. Psychological treatment is the best course of action for functional HL.

Mixed Hearing Loss

A combination of sensorineural and conductive hearing loss is referred to as mixed HL. This can encompass damage in both the inner ear and the outer or middle ear that can be temporary or permanent. This damage can result in HL ranging from mild to profound. Mixed HL is treated medically or with surgery.

Conductive and mixed HL often result from infection with certain viruses. Trauma is also a frequent cause of conductive or mixed HL. Penetrating foreign bodies can result in small perforations in the anteroinferior portion of the tympanic membrane, as well as larger perforations in other regions (Lasak, Allen, McVay, & Lewis, 2014). Amplification or stapedectomy are used to treat progressive conductive or mixed hearing loss that occurs as a result of bony deposition at the stapes footplate impeding regular movement in the oval window (Lasak, Allen, McVay, & Lewis, 2014).

Conductive Hearing Loss

Conductive HL is attributed to damage or obstruction of the passages in the outer and / or middle ear. This often leads to problems transferring sound waves along the pathway through the outer ear, tympanic membrane (eardrum), or middle ear (ossicles). Unilateral conductive HL is often the result of external or middle ear disease, and can also occur following a virus. The cause of conductive HL can usually be determined through examining the auditory canal and tympanic membrane. Otosclerosis is the leading cause of HL in adults without a prior history of middle ear effusion or otitis media (Lasak, Allen, McVay, & Lewis, 2014). Medical or surgical treatment is primarily used to treat conductive HL, and usually results in full restoration of hearing (Cunningham & Tucci, 2017). However, conductive HL can also, in some cases, require amplification. For conductive hearing loss that cannot be treated with conventional amplification, bone-anchored HA may be an option. Conductive HL ranges from mild to profound and can be temporary or permanent.

Sensorineural Hearing Loss

Sensorineural HL is a dysfunction of the inner ear, outer hair cells of the cochlea, or auditory nerve. It is the most common type of HL and it is permanent. Sensorineural HL ranges from mild to profound and the primary treatment is amplification (HPDs). Noise induced HL is a type of SNHL. Sensorineural HL can also be caused by viruses, tumours, or autoimmune disorders, or simply a result of aging.

While certain viruses can lead to conductive or mixed HL, HL resulting from viruses is typically sensorineural. Asymmetrical SNHL can be an indication of Meniere's disease or acoustic neuroma (auditory nerve tumours). Acoustic neuromas are often accompanied by: asymmetrical hearing loss; tinnitus; imbalance; low speech discrimination scores; and abnormal auditory brainstem response (Lee et al., 2015; Suzuki, Hashimoto, Kano, & Okitsu, 2010). When evaluating asymmetrical SNHL a retrocochlear cause must be ruled out. This is chiefly done using magnetic resonance imaging (Chau, Cho, & Fritz, 2012; Lee et al., 2015; Suzuki et al., 2010).

Sudden Sensorineural Hearing Loss

Noise induced HL is a type of SNHL resulting from noise exposure compounded over time. In contrast, idiopathic sudden SNHL has an onset of a period of less than 72 hours (Plaza, Durio, Herraiz, Rivera, & Garcia-Berrocal, 2011). Commonly referred to as sudden deafness, this type of HL is unilateral and cannot be attributed to noise or ontological disease (Plaza et al., 2011). The cause is presumed to be viral, vascular, or autoimmune-related (Cunningham & Tucci, 2017). Sudden SNHL is diagnosed through otoscopy, acoumetry, tonal audiometry, speech audiometry, tympanometry, and magnetic resonance imaging (Plaza et al., 2011). Treatment is primarily systemic corticosteroids (Lasak, Allen, McVay, & Lewis, 2014; Plaza et al., 2011). Outcomes including: dBs recovered in PTA; improvement in recovery rate in unilateral cases; and improvement in speech audiometry, are measured at seven, 15, 30, and 90 days after treatment, with a follow up after 12 months (Plaza et al., 2011).

While sudden deafness is commonly treated with pharmacological therapy, current evidence for oral corticosteroid treatment is contradictory in outcome and is currently under debate (Chau, Cho, & Fritz, 2012). The efficacy of these treatments may also be limited due to the blood-cochlear barrier limiting the ability of drugs to penetrate the inner ear (Rivera et al., 2012). In addition, there can be adverse secondary effects caused by systemic treatments (Rivera, Sanz, Camarero, & Varela-Nieto, 2012). While new therapies are being developed that deliver the drug directly to the inner ear, they are mostly still being tested in animal trials (Rivera et al., 2012).

Differentiating Sensorineural Hearing Loss From Age Related Hearing Loss

It can be more difficult to differentiate HL attributed to aging from other types of HL, particularly SNHL. This is especially so when assessing hearing disorder among older people. By 50 years of age, it can be difficult to determine the contribution of noise exposure to the normal progressive loss of hearing due to aging (Ali, Morgan, & Ali, 2014). By 70 to 80 years of age, HL has evened out between those not exposed and those exposed to occupational noise (Ali et al., 2014). Thus, it is recommended that clinicians account for age when determining the work relatedness of NIHL. As previously mentioned, data from ISO 1999 can be used to estimate the contribution of age on HL (Dobie, 2015; Guest, Boggess, & Attia, 2012).

An anchor point of 1 and 8 kHz is commonly used to diagnose NIHL (Ali et al., 2014). Similarly, the frequency of 8 kHz is used as a reference point when assessing ARHL (Ali et al., 2014). However, as a frequency of 8 kHz could potentially be a result of noise damage, it cannot reliably indicate age related HL (Ali et al., 2014). The anchor point concept has a fixed total; meaning that as damage attributed to one cause increases, the damage attributed to a second cause must decrease (Ali, et al., 2014). Thus, anchor point frequencies fail to account for the nuances of the relationship between noise damage and damaging due to aging. This method may, therefore, not always reliably distinguish between NIHL and age related HL. In contrast, a variable ratio model indicates that ears more prone to damage from one source (e.g., noise) will also be more prone to damage when aging (Ali et al., 2014). This is due to the similarity of the pathology between the two causes of hearing loss (i.e., inner ear hair cell deterioration; Ali et al., 2014). This method considers both contributors to HL simultaneously, and may provide a more accurate depiction of losses resulting from both noise and age.

Audiometric notches are also used to distinguish between NIHL and ARHL, with the presence of notches often considered to be an indication of NIHL. Noise-induced HL is often characterised by the presence of an audiometric pattern of selective high-frequency, bilateral, symmetrical loss (Attias, Karawani, Shemesh, & Nageris, 2014) with notches or bulges, most commonly in the region of 3 to 6 kHz, with lesser damage at 9 kHz (Ali et al., 2014; Flamme et al., 2014). Audiometric notches are most prevalent at 4 kHz and 6 kHz (Ali et al., 2014; Flamme et al., 2014). Conversely, age related HL can be characterised by monotonically increasing thresholds with frequency (Flamme et al., 2014), with greater damage at 8 kHz, and lesser damage around 4 kHz (Ali et al., 2014). These patterns may help to distinguish between NIHL and ARHL.

Yet, while NIHL often results in high frequency notches, not all cases will present with notches. Contemporary research has also indicated that the presence of high frequency notches is common among other types of hearing damage (Osei-Lah & Yeoh, 2010), and notches often occur in people who have not been exposed to excessive noise (Lie, Skogstad, Johnsen, Engdahl, & Tambs, 2014). Thus, while notches may be interpreted as an indication of NIHL, other indicators are required to substantiate a diagnosis of NIHL. Yet, NIHL is still often characterised by the presence of a notch. However, it is also common for experts to disagree on what constitutes a real notch.

A recent study of ONIHL in male railway workers assessed three types of notched audiograms: Coles notch; notch index; and 4 kHz notch (Lie et al., 2014). Coles notch was present in 63% of male railway maintenance workers exposed to noise levels of 75 to 90 dB(A) compared to 53% of non-noise exposed (<70 dB[A]) male traffic controllers (p<.001). For the notch index, 61% of the noise exposed male workers compared to 51% of the non-exposed male workers had a notched audiogram (*p*<.001). For the 4 kHz notch, 31% of the noise exposed male workers compared to 21%of the non-exposed male workers had a notched audiogram (*p*<.001). Thus, in this study we can see an increase of notches in noise-exposed workers compared to non-exposed workers. However, findings also indicated that age was positively correlated to an increase in the prevalence of notches (Lie et al., 2014). Sex was also found to impact the prevalence of notches. Females had fewer notches overall (approximately half that of men), and the difference between non-exposed and exposed female workers was smaller than in males (Lie et al., 2014). Thus, the correlation between occupational noise exposure and notches is weaker for women than men. These findings indicate the need to consider confounding factors, such as age and gender, when diagnosing ONIHL.

A similar study of NIHL examined the prevalence of four types of audiometric notches (Coles, Hoffman, Wilson, and 4 kHz notch) in relation to age, sex, report of recurrent ear infections, and occupational noise exposure (Lie, Engdahl, Hoffman, Li, & Tambs, 2016). The Wilson, Hoffman, and Coles notches

(notches in the 3 to 6 kHz range) were more prevalent in people who had been exposed to occupational noise (60% to 70%) compared to people without occupational noise exposure (50% to 60%). However, the differences were only statistically significant for bilateral notches. For 4 kHz notches, the prevalence (25% to 35%) was statistically significant for bilateral and unilateral notches in men exposed to occupational noise. The prevalence of notches was lower in women than in men, especially for 4 kHz notches. The difference in prevalence of notches between noise exposed and non-exposed women was also smaller. Interestingly, recreational exposure to loud music was not associated with notched audiograms. These findings support the earlier findings of Lie, Skogstad, Johnsen, Engdahl, and Tambs, (2014), and reiterate the need for clinicians to account for confounding factors (i.e., age, gender), and also establish a history of hazardous noise exposure before making a diagnosis of ONIHL. Yet, the presence of notched audiograms can still be a good indication of ONIHL, especially in men (Lie et al., 2016; Lie et al., 2014).

Noise Induced Hearing Loss Testing and Assessment

In some instances, such as screenings of large populations, people can receive training to conduct audiometry assessments (e.g., nurses, administrators). However, otolaryngologists, audiologists, and audiometrists are the most qualified to perform audiometric testing, and should be the ones to interpret the results.

Otolaryngologists

- An ear, nose, and throat (ENT) doctor (sometimes termed an otolaryngologist) is a medical specialist who has additional training in evaluating and treating hearing loss, and diseases related to the ear nose and throat.

Audiologist

- A clinician who has completed an undergraduate university degree as well as a masters degree in audiology.

Audiometrist

- A clinician who has completed a certificate course in hearing assessment and hearing aid fitting and management.

Assessment of Occupational Noise Induced Hearing Loss For Worker Compensation

As previously mentioned, it can be difficult to determine whether HL is a result of exposure to noise or can be attributed to aging. However, it is important that the assessment for ONIHL makes every attempt to discriminate between HL resulting from noise exposure and HL related to aging or other causes.

The three accepted methods for assessing age related to ONIHL worker compensation claims are thresholds, age or time restriction, and age correction. Thresholds refer to high HL thresholds. Age or time restriction stipulates that a claim can be lodged during the worker's working life or within a limited time after their retirement. Age correction involves a specific amount of decibels being extracted from the average HL over various frequencies.

The application of an age correction using National Acoustic Laboratories tables is adopted in most Australian states, including NSW, when assessing workers compensation claims of ONIHL. The National Acoustic Laboratories tables are based on 'Improved Procedure for Determining Percentage Loss of Hearing' NAL Report No. 118, January 1988. The NAL tables and ISO-1999 data calculate HL thresholds while taking into account the potential contribution of gender and aging when estimating the risk of HL from noise exposure. In NSW, the National Acoustic Laboratories Table for the allowance of presbycusis is applied when assessing NIHL. The frequency range is 0.5 to 8 kHz. These tables can be used to calculate binaural and monaural percentage of HL. However, National Acoustic Laboratories Tables are based on an older version of the ISO 7029 standard. It is recommended that these tables be based on the more current ISO-1999 standards.

Diagnosing Noise Induced Hearing Loss

To diagnose NIHL, clinicians must have an understanding of factors that can contribute to HL caused by excessive noise, as well as the pathophysiology of NIHL. Thus, otolaryngologists and audiologists are uniquely qualified to diagnose ONIHL, as they have a comprehensive understanding of the clinical and audiometric characteristics of NIHL. In medico-legal cases where workers compensation is being considered for ONIHL, a diagnosis from a qualified otolaryngologist is required, however, they usually employ an audiologist to do the audiometry testing. The progression and degree of loss, whether it is unilateral or bilateral, and the presence or absence of vertigo and tinnitus must be established when diagnosing NIHL.

Australian audiology and audiometry industries are self-regulated with three primary practitioner professional bodies that represent audiologists and audiometrists: Audiology Australia; the Australian College of Audiology; and the Hearing Aid Audiology Society of Australia. Audiology Australia represents audiologists. The Australian College of Audiology represents both audiometrists and audiologists. The Hearing Aid Audiology Society of Australia represents audiometrists only. Audiologists and audiometrists must be a member of one of these professional bodies in order to provide hearing services under the Australian Governments Hearing Services Program.

The standard clinical practice for diagnosing SNHL involves a full clinical history, audiometry screening, and a clinical interpretation of the findings. When assessing workers clinical history, medical risk factors for SNHL are assessed and neuro-otological symptoms are considered. Clinicians must also take note of workers noise exposure history, their use of protective equipment, and any exposure workers may have had to potentially damaging toxic agents (e.g., industrial substances). Any concerns regarding balance are also discussed. Audiological screening by way of otoscopy, tympanometry, speech testing, and conventional 8-frequency PTA will then take place. Clinicians will then interpret the results and discuss them with their client. In cases where HL is present, clinicians will make recommendations for treatment and management.

The Australian Society of Otolaryngology Head and Neck Surgery Guidelines for Otolaryngology Referral Prior to Hearing Aid Fitting

The Australian Society of Otolaryngology Head and Neck Surgery guidelines state that approved HL assessors are qualified to diagnosis and assess NIHL after a comprehensive ontological examination and conventional PTA. Additional testing (i.e., impedance and speech audiometry, cortical electric response audiometry) can be used if necessary. The guidelines relating to ONHIL state that contribution from occupational and non-occupational noise can be estimated from serial audiograms and the duration of exposure to excessive noise in the workplace. They stipulate that active middle ear disease, perforation of the eardrum, or co-existing symptoms (i.e., vertigo, unilateral tinnitus) require further assessment by an Otolaryngologist. The Australian Society of Otolaryngology Head and Neck Surgery guidelines state that HAs are the primary treatment for SNHL.

Evidence and Scope of Practice

Contemporary research supports the current practice of otolaryngologists and audiologists diagnosing ONIHL, primarily with PTA conducted in a sound-protected environment (Chau et al., 2012; Dillion et al., 2016; Fredriksson et al., 2016). It is also the method utilised by the National Hearing Service. As such, this is the recommended practice for workers compensation cases. Additional sources of evidence can also be used to support PTA when making a diagnosis of ONHIL, especially in workers compensation cases. Clinicians use their expertise to consolidate: otoscopy results; audiometry findings (i.e., PTA); prior medical history (e.g., tinnitus, ear infections); risk factors (e.g., exposure to ototoxic drugs, tinnitus, diabetes, smoking); and confounding factors (e.g., gender, age). Thus, when assessing HL, clinicians determine the contribution of occupational noise-exposure to SNHL, rule out other potential causes of SNHL (e.g., acoustic neuroma), and make recommendations for workers compensation claims.

Pure tone audiometry conducted by otolaryngologists and audiologists is often impractical for screening large populations, as it can be costly and time consuming. Conducting hearing screening using more time and cost efficient tests (i.e., Occupational Earcheck, Digits-in-Noise test) to identify people who are in need of additional more conventional testing (i.e., PTA) is supported by contemporary research (e.g., Convery et al., 2014; Meinke et al., 2018; Rashid & Dreschler, 2018; Rashid et al., 2017).

Hearing Aid Use

Hearing aids have been found to be effective for treating mild to moderate NIHL, so long as the customer is motivated and the device is properly fitted (Kochkin, 2011; Kochkin et al., 2010). During HA fitting, audiologist test that the HA is working and program the HAs to optimise amplification and speech capabilities, while keeping amplification at a comfortable level. Compliance rates for HAs are estimated at approximately one in four. However, they are slowly increasing along with customer satisfaction with HAs (Kochkin, 2010). Just over half (55%) of people surveyed during a study on HA customer satisfaction indicated that they were 'satisfied' or 'very satisfied', and another 23% indicated they were 'somewhat satisfied' with their current HA, (Kochkin, 2010).

The MarkeTrak VIII HA customer satisfaction study (Kochkin, 2010) has provided a list of the top 10 factors that impact customer satisfaction with HAs: (1) overall benefit; (2) clarity of sound; (3) value; (4) natural sounding; (5) reliability of the HA; (6) richness or fidelity of sound; (7) use in noisy situations; (8) ability to hear in small groups; (9) comfort with loud sounds; and (10) sound of voice. This list provides insights into the issues people experience with HAs, and suggests that improvements in these key areas may increase compliance with HA use. People were mostly satisfied with practical and cosmetic factors of HAs such as: ease of changing the battery (88%); fit and comfort of their HAs (87%); ease of insertion or removal of HA (85%); and visibility of HAs (78%). However, they were less satisfied with the sound quality of HAs and HA performance in different listening situations (Kochkin, 2010). Amongst the sound quality factors with the highest negative ratings were: use in noisy situations (25%); comfort with loud sounds (19%); and ability to hear soft sounds (19%; Kochkin, 2010). The assessment of consumer satisfaction in specific listening situations revealed that 99% of people are satisfied with the ability of HAs to improve one-on-one communication (Kochkin, 2010). People also indicated that they were satisfied with their HAs: when communicating in small groups (85%); while watching television (80%); and when outdoors (78%; Kochkin, 210). However, they were less satisfied with the performance of HAs in large groups (68%; Kochkin, 2010).

An Australian study, the EARtrak survey assessed the outcomes of hearing aid fitting in private clinics using the International Outcome Inventory – Hearing Aids (IOI-HA; Cox et al., 2000) and additional questions that assessed: satisfaction with HA performance in different listening situations, HA attributes, and clinical service (Hickson, Clutterbuck, & Khan, 2010). The IOI-HA (Cox & Alexander, 2002) measures seven items: (1) hearing aid usage; (2) benefit; (3) residual activity limitations; (4) satisfaction; (5) residual participation restrictions; (6) impact on others; and (7) quality of life. Overall the majority of people surveyed indicated they were 'very satisfied' (30%) or 'satisfied' (48%) with their HAs. The four listening situations with the highest negative ratings, with less than half of people indicting they were satisfied in these situations, were listening in large groups, in the workplace, in restaurants, and on the telephone. Similar to Kochkin's (2010) study, the EARtrak study indicated that people are satisfied with the overall fit and comfort of their HAs and less satisfied with sound quality and listening situations, specifically listening in large groups (34%; Hickson et al., 2010).

While HAs are primarily used by older people, the average age of people with HAs has decreased (Kochkin, 2010). Yet, people still associate hearing impairment and HAs with older adults, and this stigma can delay the decision to use HAs among younger adults. Overall, to increase the use of HAs among workers, customer satisfaction must be increased and education provided to reduce stigmas associated with hearing impairment.

Evidence-Based Practice: Hearing Aids for Noise Induced Hearing Loss

While HAs are considered the best practice treatment for SNHL, there is a small evidence base to inform on the outcomes of HA use specifically for treating NIHL. There is a lack of prospective controlled trails that assess the efficacy of HAs for improving auditory function of people with NIHL. Thus, the evidence base behind the different types of hearing technologies (e.g., noise reduction, feedback-reduction, directional processing, and methods of compression) for treating NIHL is weak. This is partially due to the rapid advancement of technologies in the field of audiology, as well as a lack of consensus on how to measure the performance of these technologies relating to benefits for hearing impaired people. Yet, there is some evidence that providing hearing aids that provide greater amplification in the frequencies in which there is greater NIHL are more effective. These are referred to as "digital devices" (Giordano et al., 2008). These types of hearing aids are available from the Australian National Hearing Service (http://www.hearingservices.gov.au).

Self-report instruments are available that measure both satisfaction and outcomes after treatment of HL. Customer satisfaction has been assessed using the Satisfaction with Amplification in Daily Life (SADL; Cox & Alexander, 1999). Outcomes of individual client goals can be assessed with the Client-Oriented Scale of Improvement (COSI; Dillon, James, & Ginis, 1997). The benefits associated with HA use can be assessed using the Abbreviated Profile of HA Benefit (APHAB; Cox & Alexander, 1995). Despite this, the literature on the outcomes of NIHL treatment using HAs is scarce.

In addition to improving listening ability, HAs have also been found to improve the health-related quality of life of people with mild to moderate HL (Ferguson et al., 2017). Due these results, HAs have remained the primary clinical treatment and management of NIHL. Yet, while HAs can enable people with SNHL to regain some lost auditory function, people often still have impaired speech understanding, especially in noisy environments, even with the use of HAs. Auditory rehabilitation and counselling can help HA users to overcome some communication issues. Yet, auditory training and rehabilitation is still underutilized. A study by Gil and Iorio (2010) evaluated hearing pre-and-post training using the APHAB and measures of electrophysiological and behavioural auditory processing. Findings indicated that after auditory training with HAs, people with SNHL showed improvements in: sound localization; memory for nonverbal sounds in sequence; reduction in P3 latency; auditory closure; figure-to-ground for verbal sounds; and hearing in reverberant and noisy environments.

A meta-analysis of 27 studies that investigated the use of HPDs in adults with unilateral SNHL indicated that devices that reroute sound from an ear with severe to profound HL to an ear with minimal HL may improve speech perception in noise (Kitterick, Smith, & Lucas, 2016). However, as all signals are rerouted indiscriminately, including noise, these devices also have the potential to degrade speech perception (Kitterick, Smith, & Lucas, 2016). Due to the failure of studies on the use of CIs for treating SNHL to meet the criteria for meta-analysis, no clear conclusion on whether CIs can improve speech perception or the ability to localize sounds could be reached (Kitterick, Smith, & Lucas, 2016).

A systematic review of evidence-based practice in audiology determined that the use of HAs and rehabilitation interventions for adults with SNHL both act to reduce activity limitations and participation restrictions with hearing impaired people (Hickson, Laplante-Levesque, & Wong, 2013). How satisfied participants were with their current HAs in 11 different situations was assessed. These situations were: conversations with one person; conversations in small groups; conversations in large groups; conversations outdoors; hearing at concerts and / or movies; hearing at church and / or lectures; watching television; hearing in a car; hearing in the workplace; hearing on the telephone; and hearing in a restaurant. People were more satisfied with the performance of their HAs in conversations in small groups and one-on-one than in large groups (Hickson et al., 2013). People were least satisfied with the performance of the HAs in the workplace and on the telephone (Hickson et al., 2013).

However, even though people remain unsatisfied with the performance of their HAs in many situations, participation in rehabilitation interventions remains low. In one study, 43% of people chose HAs, 18% chose communication programs, and 39% refused treatment (Hickson et al., 2013). The people who chose treatment with HAs had significantly better aided than unaided speech understanding and were generally satisfied with the performance of their HAs. Yet, even though the use of HAs is increasing, compliance with HAs remains low.

Clinicians' recommendations of HPDs are often not evidence-based. Instead clinicians have been found to base their recommendations on the hearing impaired persons daily activity level, the level of HPD use for experienced users, age, and speech discrimination scores (Giola et al., 2015). The primary factors that influenced clinicians' treatment recommendations were the person's lifestyle as perceived by the clinician and speech discrimination. A very active person with good speech discrimination had a 68% change of being recommended the highest technology. In comparison, an active person with poor speech discrimination had only a 17% chance of being recommended the highest technology. Thus, clinician's recommendations on HAs and the features of HAs that would be best suited to treat a persons HL may often be client-centred as opposed to strictly evidence based.

Legislative Framework

NSW Work Health and Safety Regulation 2017

NSW Work Health and Safety Regulation 2017 addresses specific laws that control the risk of exposure to noise in the workplace. Clause 56 to 58 outline: the meaning of exposure standard for noise; managing risk of HL from noise; audiometric testing; and duties of designers, manufacturers, importers, and suppliers of plant. Clause 58 stipulates that pure tone audiometric testing be conducted with workers who are required to use protective equipment designed to protect against the risk of HL associated with noise exposure that exceeds the exposure standard for noise in the workplace. Baseline audiometry must be conducted within three months of commencing employment to provide a control measure. Audiometry is then required at least every two years.

Workers Compensation

The assessment of ONIHL claims must reflect best practice for assessment, treatment, and management while keeping in line with Australian Standards and legislation. The American Medical Association 5th Edition guidelines, Guides for the Evaluation of Permanent Impairment (2001), provide the basis for the NSW Workers Compensation Guidelines for the Evaluation of Permanent Impairment. These Guidelines provide: the legislative basis for the use of the Guidelines; assessment principles for medical practitioners when assessing permanent impairment resulting from work-related injury or disease; and administrative issues relating to the use of the Guidelines. The Guidelines outline the methods of assessment for evaluating all compensable permanent impairments, including permanent work-related hearing injuries or losses. The stipulated assessment for ONIHL is PTA.

Subsidised hearing services in Australia are managed through a division of the Department of Health, the Office of Hearing Services. The Office of Hearing Services Voucher Scheme provides both fully and partially subsidised HPDs, HPD maintenance, and support. However, workers compensation cases for NIHL are state dependent. In NSW, both Comcare and the state workers compensation legislation specify the hearing threshold for workers compensation in terms of binaural HL. The hearing threshold used to determine whether workers are potentially eligible for lump sum payments for occupational HL is 5% whole person impairment for Comcare. Comcare's Guide to the Assessment of the Degree of Permanent Impairment states that HL is to be assessed in accordance with the current procedures from Australian Hearing. The percentage loss of hearing is then converted to a WPI rating (WPI rating = percentage loss of hearing / 2). The NSW workers compensation system has a lump sum compensation threshold of 6% binaural hearing loss for both pre 2002 injuries and exempt workers, while a threshold of 11% whole person impairment applies to all other lump sum compensation claims.

There is a complex claims process for ONIHL workers in New South Wales (NSW), which can sometimes lead to disputes. One of the disputes at the forefront concerns the use of HAs, as adherence with HA use is low among workers. Hearing conservation programs for ONIHL should focus on negating the stigmas attached to the use of HAs, particularly in the workplace. Audiology rehabilitation programs should address barriers to HA use and provide training, counselling, and support with a focus on increasing HA compliance and communication.

The Australian Government Hearing Services Program

The Australian Government Hearing Services Program provides eligible clients with a range of services and subsidised devices. This program is mandatory for all workers >65 years and is the default scheme for pensioners.

The hearing services provided through the Australian Government Hearing Services Program include:

- Choice of service provider
- Hearing assessment (performed by a qualified hearing services provider)
- Support and advice on hearing loss
- Fitting of a subsidised HPD
- Contribution to the optional annual maintenance of HPD (fee applies)
- List of up to 20 services providers (in clients local area)
- Rehabilitation Plus
    - Available with fully subsidised HPD
    - Communication strategies

Hearing Devices provided through the Australian Government Hearing Services Program:

- Range of fully subsidised standard HPDs
    - Behind the ear (BTE)
    - High powered BTE
    - Open fit BTE
    - In-the-ear (ITE)
    - In-the-canal (ITC)
    - Completely in the canal (CIC)
    - Contralateral routing of signal (CROS) aids
    - Bilateral contralateral routing of signal (BiCROS) aids
    - Body aids
    - Bone conduction HAs
    - Spectacle aids
    - Alternative listening devices (ALD)
    - Price: approximately $3,900 per device
- Partially subsidised HPDs
    - Additional gap fee for selection of additional features
    - Known as a 'top-up'
    - Price range: $6,000 to $8,000 per device

- Assistive listening device (ALD)

Treatment

Best Practice Treatment for Noise Induced Hearing Loss

There are three treatment modalities for HL: medical, surgical, and amplification. The choice of treatment will depend on the type of HL. Infectious and systemic aetiologies of HL can be treated with pharmacological therapy (i.e., steroids, antibiotics, antioxidants; Lasak, Allen, McVay, & Lewis, 2014). Infectious or traumatic etiologies of HL can be treated with surgery (e.g., chronic otitis media, congenital aural atresia; Lasak et al., 2014). Amplification is the primary treatment for most other types of HL, including NIHL. Best practice treatment for ONIHL includes: provision of HPDs; rehabilitation (i.e., client education and communication training); and psychological and social support.

Rehabilitation

It is agreed in both the audiology industry and the literature that the provision of HPDs is only one aspect of the treatment for NIHL. Support, training, counselling, and auditory rehabilitation are of equal importance to maximise both HPD compliance and communication outcomes. A recent study that looked at the decision-making behaviour of audiologists pertaining to audiometry rehabilitation choices for clients has indicated that the two foremost factors that influence decision-making are test results and client preference, followed by discussion with experts or colleagues (Boisvert et al., 2017). When no clear intervention presented itself, 20% of audiologist indicated that they would consult research evidence (peer-reviewed literature and textbooks) to guide their decision-making (Boisvert et al., 2017). Thus, we can see that when it comes to clinician recommended rehabilitation for hearing impairment, scope of practice is more client-centred than evidence based.

Kotchkin et al. (2010) has indicated that few hearing impaired people receive rehabilitation, counselling, or information regarding self-help groups. They reported that people receive an average of 1.2 hours of counselling during the two months that follow their initial HA fitting, and only have 2.5 visits to fit their HAs (Kotchkin et al., 2010). It is important that clinicians who diagnose NIHL discuss the range of rehabilitation interventions available to workers with ONIHL.

Volunteer organisations such as Better Hearing Australia and Self Help for Hard of Hearing People Australia provide education, counselling, and support for people with hearing impairment. Communication programs such as these can be individualised or group based, and usually focus on communication management, improvement of speech perception, stress management, and personal adjustment.

Rehabilitation for NIHL is centred on maintaining hearing, speech, and language. Rehabilitation interventions should include: speech perception in a variety of environments; localisation of sound sources (e.g., cars, footsteps); detection of environmental signals (e.g., ringing telephones, alarms, doorbells); and understanding of broadcast signals (e.g., radio, television; Laplante-Levesque, Hickson, & Worrall, 2010). Individual auditory training programs have been found to improve speech perception (Hickson, Laplante-Levesque, & Wong, 2013), and counselling-based group rehabilitation programs have been found to reduce activity limitations and participation restrictions (Hickson et al., 2013). People with hearing impairment should be actively involved in their rehabilitation, as maintaining communication is vital for social functioning and mental health. However, a review of seven studies on the effect of audiological rehabilitation programs (education and counselling programs) on HR outcomes indicated that while rehabilitation programs have been found to bolster communication strategies, they do not increase the use of HAs (Aazh & Moore, 2017).

There is paucity in the literature relating to rehabilitation interventions and treatment outcomes specifically for NIHL. Thus, it remains unclear whether the lack of rehabilitation for workers diagnosed with ONIHL is due to poor availability or poor uptake. Additionally, there are continuing impediments to the rehabilitation of workers with ONIHL. The stigma that these programs are for older adults suffering from ARHL can prevent people from partaking in them. In order for people to commit to rehabilitation and comply with HA use, changes in attitudes regarding hearing impairment and increased acceptance of HAs are necessary. These barriers to rehabilitation should be addressed in hearing rehabilitation interventions. Longitudinal research on outcomes of ONIHL treatment and rehabilitation with an economic focus is needed to inform on the benefit-to-cost of rehabilitation interventions and HPD provision.

Summary of Standard Rehabilitation Practices

- Assessment of needs
    - Identify priorities / goals of rehabilitation
    - Identify current communication skills
    - Identify communication needs
- Counselling
    - Identify communication ability
    - Communication training (i.e., utilizing nonverbal cues, lip-reading)
    - Assess awareness of environmental sounds
    - Improve knowledge of auditory disorder / limitations
    - Provide coping strategies
    - Improve quality of life
    - Manage expectations
    - Address barriers to use of HPDs (i.e., cost, negative stereotypes, comfort, confidence)
- Amplification strategies (HPDs)
    - Management
    - Usage
    - Benefit
- Outcome measures and evaluation
    - Identify change in auditory / communication function
    - Monitor progress of rehabilitation program
    - Evaluate goals / expectations
    - Identify further need for rehabilitation, assessment, or referral

Hearing Protection Devices (HPDs)

Personal hearing devices are the best practice treatment for ONIHL. However, people should be made aware of the limitations of such devices, as well as what can be achieved with the use of HPDs. People are often disappointed with the results they achieve with HAs. This frequently leads to non adherence with treatment recommendations and discontinued use of HAs altogether. The use of HPDs should be coupled with counselling, education, and training to manage people's expectations around their capabilities and limitations, and to maximize their usage and communication efficacy.

Summary of Type of Hearing Protection Devices (HPDs)

Hearing protection devices can offset hearing loss caused by noise exposure - improving hearing ability.

- Hearing aids (HAs)
    - Analog
        - Different settings for different listening environments
    - Digital

        - Additional features not available with analog HAs
        - Reduce acoustic feedback
        - Reduce background noise
        - Accommodate different listening environments
- Assistive listening devices (ALDs)
- Implantable devices (e.g., cochlear implants)
- Sensory devices

Limitations

    - Noise levels can exceed their protective capacity
    - Acoustic energy can bypass HPDs and be transmitted directly through the skull
    - The need for audible communication can be limited by HPDs
    - Poor compliance with treatment recommendations
    - Lack of fit
    - Exposure to sudden, damaging noise during a time when HPDs are not being worn
    - People often still have difficulty understanding speech in background noise

Hearing Aids (HAs)

There have been substantial improvements in HAs over the years. They are now more comfortable, smaller, easier to use, and capable of producing more natural sound. However, individual HAs do differ on size, placement (i.e., in or outside of the ear), and their ability to amplify sound. The type of HA that is selected will depend on: ease of use, cleaning, insertion; appearance; comfort of fit; type of HL; and cost. The recommendation of a clinician can also largely impact the selection of HAs.

Conventional HAs have been used to treat mild-to-severe SNHL with much success. Yet, in some cases HAs are deemed inappropriate due to medical conditions, skin irritation or allergies, narrow external ear canals, or chronic otitis externa (i.e., swimmers ear; Maier et al., 2015). Practical problems include: inserting; removing; cleaning; changing batteries; controlling volume; coping with extraneous noise (e.g., whistles). In cases such as these, semi-implantable middle ear devices may be the preferred treatment option. People often prefer, and are more likely to use, in-the-canal or in-the-ear aids. Thus, treatment options and management strategies are based on each individual's unique presentation, requirements, and experience of NIHL.

Summary of Hearing Aid Type (see Table 1):

- Behind-the-ear (BTE)
    - Versatile
    - Custom ear mould or dome that fits within the ear canal
        - Open fit Behind-the-ear
            - For people who cannot wear an ear mould
            - Useful for people who have good hearing for low pitch sounds
        - High powered Behind-the-ear
            - Severe to profound HL
            - Larger (larger battery)
        - Contralateral routing of signals (CROS)
            - Unilateral HL
            - Deliver sound from the impaired ear to the functioning ear
            - Poor user satisfaction
        - Bilateral routing of signals (BiCROS)
            - Bilateral HL
- In-the-ear (ITE)

  - Smaller size than Behind-the-ear
  - More powerful / larger than ITC
  - Vulnerable to wax damage / wear and tear
- In-the-canal (ITC)
  - Smaller than BTE
  - Vulnerable to wax damage / wear and tear
  - Lightweight and discreet
  - Versatile amplification
  - Custom ear mould or dome that fits within the ear canal
- Completely in-the-canal (CIC)
  - Smaller than other HAs
  - May have less power / features (due to small size)
  - May not be suitable for narrow / 'bendy' ear canals
  - May not be suitable for people with impaired dexterity
  - Vulnerable to wax damage / wear and tear
- Custom
  - Moulded to the shape of the persons ears
  - Easy insertion / removal
  - Discreet

Bone Anchored Hearing Aid (BAHA)

In an investigation of the uptake of BAHA by 90 people with unilateral SNHL, 87.8% of people were found to be audiologically suitable for the implant (Siau, Dhillon, Andrews, & Green, 2015). Twenty-four of those people opted to have the BAHA implanted, while 55 declined. Thirty-two of those people opted for a wireless contralateral routing of sound device over the BAHA implant. The reasons people chose not to go ahead with the implant were: perceived limited benefits (47.3%); reservations regarding surgery (32.7%); preferred a wireless contralateral routing of sound device (23.6%); and cosmetic reasons (21.8%). Thus, while audiological suitability may prevent some people from obtaining an implantable device, personal preference will also impact people's choice of HPD.

Cochlear Implant (CI)

In cases of severe to profound SNHL, inner-ear hair cells may be unable to stimulate the auditory nerve in response to sound (Cunningham & Tucci, 2017). Conventional HAs may, therefore, not be effective for people with severe to profound bilateral SNHL. Due to this, people who do not establish satisfactory communication with conventional HAs or have increased communication demands may be candidates for CI. Cochlear implants are surgically implanted to bypass the cochlear hair cells and electrically stimulate the auditory nerve (Cunningham & Tucci, 2017). Cochlear implants bypass a non-functional cochlea and directly stimulate the cochlear nerve. However, to be a candidate for CI, the cochlear nerves must be functional (Lasak, Allen, McVay, & Lewis, 2014). For people without a functional cochlear nerve, auditory brainstem implant may be an alternative option (Lasak et al., 2014). Non-Linguistic Psychoacoustic Measures (e.g., spectral-ripple discrimination test) can help evaluate CI candidacy (Shim et al., 2014).

The following factors must be considered when assessing CI candidacy: surgical risk; no medical contraindications; demonstrated lack of benefit from rehabilitation with HAs; commitment of the candidate; and social support (Sprinzl & Riechelmann, 2010). Adult selection criteria for CI candidacy have been determined through analysing the post-operative performance of adults who received implantation. Recently, an Australian study suggested revised audiological guidelines after assessing the CI of 382 postlingually deafened adults (Leigh, Moran, Hollow, & Dowell, 2016). They suggest that adults with postlingual HL who obtain scores of up to 55% for open-set phonemes and / or word scores of up to 26% in quiet in the ear to be implanted should be considered for CI. A 75% chance of improvement in the implanted ear guided this recommendation.

While it has been well established that CIs are effective for improving communication-related outcomes for people with bilateral HL, more recent findings have also indicated their efficacy in improving hearing and quality of life for unilateral HL (Gaylor et al., 2013; Stelzig, Jacob, & Mueller, 2011). Cochlear implants have also been shown to improve speech functioning (Lasak, Allen, McVay, & Lewis, 2014; Stelzig et al., 2011), and bilateral implantation has been shown to improve sound localization (Gaylor et al., 2013). Cochlear implants have been found to be superior to contralateral routing of signal (CROS) aids, bilateral contralateral routing of signal (BiCROS) aids, and bone conduction deceives for improving speech comprehension, and localisation has also been found to improve with CI compared to bone conduction devices (Arndt et al., 2017).

The efficacy of CI is comparable with HAs and people often prefer CI, as they can reduce sound feedback and improve sound discrimination better than conventional HAs (Arndt et al., 2017; Gaylor et al., 2013). These improvements in hearing and communication can lead to improvements in peoples social and occupational functioning. Despite these findings, the Australian Society of Otolaryngology Head and Neck Surgery has estimated that only 10% of people who would benefit from a cochlear implant have received one. This is primarily due to the cost of these implants and the lack of awareness regarding HL treatments.

Middle-Ear Implant

A systematic review of 17 studies also compared the efficacy and safety of middle-ear implants and conventional HAs for SNHL (Kahue, Carlson, Daugherty, Haynes, & Glasscock, 2014). Findings indicated that functional gain and word recognition improvements are similar with HAs and middle-ear implants. However, only one study found a significant improvement with middle-ear implants for functional gain compared with HAs. Seven studies indicated there was no significant advantage of middle-ear implants over HAs for speech recognition. Four studies found an improvement in speech recognition with middle-ear implants compared to HAs. In addition, people generally perceived middle-ear implants to enhance sound clarity, diminish feedback, and eliminate occlusion effect. Only one study indicated middle-ear implants were inferior to HAs for speech recognition. Thus, while people who receive MEIs may report greater satisfaction and better sound quality than people who have conventional HAs, the audiometric benefits of middle-ear implants and HAs are comparable.

Another systematic review of 14 studies compared the efficacy of active middle-ear implants with external HAs for people with SNHL, with nine studies reporting on the primary outcome of functional gain (Butler, Thavaneswaran, & Lee, 2013). In one study, middle-ear implants were found to be significantly better than HAs ($p<.001$). Conversely, another study found HAs were significantly better than MEIs ($p<.05$). Six of the studies reviewed indicated that middle-ear implants are better than HAs, however, this was not clinically significant (>10dB). They concluded that HAs and middle-ear implants are equally effective in improving hearing outcomes for people with SNHL. Due to these conflicting findings, no clear conclusion can be reached regarding the benefit of middle-ear implants over HAs. Middle-ear implants are not currently subsidised by the National Hearing Service. There is Medicare Benefit Item number for the procedure of implanting these devices but the eligibility criteria are very strict and rarely likely to be met. The cost of implants (middle-ear, cochlear, and bone-anchored HAs) can range from $30,000 to $50,000.

Table 1. Different Types of Hearing Aids for Sensorineural Hearing Loss

	Behind-the-Ear (BTE)	In-the-Ear (ITE)	In-the-Canal	Completely-in-the-canal (CIC)	Contralateral Routing of Signals (CROS) and Bilateral Routing of Signals (BiCROS)
Strengths	-Mild to profound HL -High powered -Background noise reduction -Feedback cancellation -Connectivity -Clear sound quality -Wireless technology -Good for excessive earwax / draining ear -Good for higher frequency HL -More space for electronic components -Earmold can be customized -Easy to handle / insert / adjust -Long battery life -Capable of more amplification than other style	- Mild to severe HL - More powerful than ITC - Smaller than BTE -Volume control (some via remote control) -Program selection (some via remote control) -Individually adapted to the ear -Suitable for spectacle wearers -Comfortable during sports -Natural sound -Easier to handle -Easy to clean -Less likely to become loose when talking / chewing -Long battery life -Easy to insert / remove -Good for people with manual dexterity issues -Good for people with poor eyesight	- Mild to severe HL - Smaller than BTE	-Mild to severe HL - Smaller than other HAs -Improved sound feedback -Improved sound discrimination -Less likely to pick up wind noise	-Feeling of balanced hearing -Wide hearing range -'Head-shadow effect' is reduced
Limitations	-Low noise management -Low adaptive directionality -Sensitive to wind noise -Potential space limitations for spectacle wearers	-Use depends on shape / size of ear canal -Susceptible to ear wax / moisture -More occlusion -Can have problems connecting to wireless	- Vulnerable to wax damage / wear and tear -Can be difficult to adjust features	-May have less power / features (due to small size) -May not be suitable for narrow / 'bendy' ear canals -May not be suitable for	-Not effective in background noise

		devices -Vulnerable to wax damage / wear and tear -Vulnerable to moisture -Sensitive to wind noise		people with impaired dexterity -Vulnerable to wax damage / wear and tear -Short battery life -No extra features -No volume control -No directional microphone	
Features related to occupational requirements	-Improves hearing	-Improves hearing -Good retention in the ear -Ease of use when using the telephone	-Improves hearing -Versatile amplification	-Improves hearing -Improves speech performance -Improves speech understanding	-Improves hearing -Improves speech understanding -Improves ability to locate sound direction -Improves ability to identify sound -Improves auditory fatigue
Features related to functional return	-Improves hearing - Noise reduction	-Improves hearing -Reduces feedback -Good retention in the ear -Ease of use when using the telephone -Can fit a telecoil -Can provide directional microphones (background noise reduction)	-Improves hearing -Versatile amplification -Minimal improvement in speech discrimination -No improvement in sound localization -Noise reduction	-Improves hearing -Improves speech performance -Improves speech understanding -Noise reduction	-Improves hearing -Improves speech understanding -Improves ability to locate sound direction -Improves ability to identify sound -Improves auditory fatigue
Recommended for ONIHL	Yes	Yes	Yes	Yes	Yes CROS – unilateral BiCROS - bilateral
Available on NHS	Yes	Yes	Yes	No	Yes

Clinical Indicators for Determining the Type and Cost of Hearing Aid That is Prescribed

Clinicians coordinate a treatment plan and recommend a type of HPD based on the requirements of the individual person, and adjust it to meet their needs. However, as a result of treatment and management, a person's situation may change. This may necessitate a change in the treatment plan or HPDs that are required. Additionally, people should be informed as new treatments and aids become available. Therefore, the type and cost of HPDs prescribed will vary depending on the current individual needs of each person, and the treatment should be patient-centred.

The selection of HPDs will vary depending on:

- Audiological test outcomes
- Number of HAs required (1-2)
- Size of ear canal
- Amount of ear wax / discharge in the ear canal
  - This can cause well-fitted HAs to feedback
- Lifestyle (sedentary / active)
- Budget / Cost
- Style / preference of HA
- Comfort of HA
- Client need for control of HA
- Ability of client to manage HA
- Client communication needs and goals
- Client agreement
- Risk factors (e.g., tinnitus)
- Compatibility with other devices
- Prognosis
  - Hearing
  - Medical conditions that may impact HAs
- Cochlear implant (CI) candidacy

The cost of hearing aids will vary depending on:

- Number of HAs required (1-2)
- Type / style of HPD
- Addition of customizable features
- Health insurance rebate
- Workers compensation insurance eligibility

Hearing aid prices will vary depending on the technology (features) and programs available in the HA. The cost can be broken down into three technology tiers: standard technology (starting at $1,500); advanced technology (starting at $2,500 - $3,000); and premium technology (starting at $3,500 - $4,500). Thus, the cost of HAs can range from around $1,500 up to $15,000 per pair. While price can be a reflection of style and features, it may sometimes also be a reflection of brand. When assessing the type of HA a person needs, it is important to consider whether the features of some more expensive models serve the needs of the individual or are superfluous. People should only pay for the features they need and will be able to make use of. Clinicians and consumers should be offered comprehensive, impartial information that can be used to choose a HA that meets their needs and their budget.

The service of fitting HAs is often coupled with the cost of HAs. The itemised cost of the diagnostic testing, fitting, and HPD should be disclosed. Treating and managing ONIHL should be person-centred and conducted by an independent healthcare provider, whose recommendations on HPDs is not influenced by anything other than the clients specific requirements. A study of the dispensing rates of HAs indicated that the decision of audiologist to recommend a HA is largely based on price, as well as their belief about which features might benefit the patient (Johnson & Ricketts, 2010). This reflects a client-centred approach to the dispensing of HAs by audiologists.

As HL resulting from exposure to excessive noise will not worsen after the exposure has ceased, any additional loss after that point can be attributed to aging or an additional type of HL (e.g., HL resulting from virus or disease). Thus, workers compensation schemes should not be required to manage additional HL after the initial diagnosis of ONIHL.

Outcomes

Measuring the Outcomes for Occupational Noise Induced Hearing Loss Claims

The outcomes for ONIHL claims should reflect the impact ONIHL has had on the injured persons health and well-being. This can be done through assessing the following levels of functioning and ultimately the person's satisfaction with their treatment:

Goals

- Measurable goals of lodging a claim for ONIHL
- Rehabilitation, communication, and hearing goals

Physical effects

- Activity limitations (restrictions on daily activities)
- Participation restrictions (difficulties being involved in everyday life situations)
- Impaired communication
- Sleep disturbance
- Audiological fatigue

Psychological and social effects

- Social isolation (through reduced ability to communicate)
- Difficulty forming / maintaining relationships
- Change in quality of life
- Memory loss
- Impaired decision making
- Depression
- Anxiety

Economic effects

- Employment and income disruption
- Compensation (if unable to return to work)
- Cost to business of providing health care services / workers compensation

Treatment outcomes

- Hearing function with selected HPD
- Satisfaction with the support they have received
- Satisfaction with their level of functioning after treatment

Outcomes for ONIHL claims could be measured through self-report questionnaire or an interview with a health professional. Measuring outcomes at the beginning and end of a claim, as well as 12 months after the end of a claim is recommended in order to assess changes in health status.

For workers

Permanent HL can occur with exposure to excessive occupational noise. The risks and consequences of working in environments with hazardous noise should be made known. Workers should be encouraged to value and trained to protect their hearing before it is damaged. Workers should be urged to report noise issues to their manager or Health and Safety Representative.

For insurance regulators

The best practice diagnosis for ONIHL is PTA. The best practice treatment for ONIHL is amplification using HAs. However, overall prevention is the best strategy.

Treatment and Recovery

Noise-induced HL resulting from occupational noise exposure is widespread in today's industrial industries, as well as other professions (e.g., armed forces, police and fire services, professional musicians). Yet, the potential for reducing the economic and social burden of NIHL is high, as there are measures to both prevent and treat ONIHL.

Otolaryngologists and audiologists diagnose and treat ONIHL using PTA (Chau, Cho, & Fritz, 2012; Dillion et al., 2016; Fredriksson et al., 2016). A comprehensive diagnostic audiometric test battery encompassing both PTA and speech-in-noise testing is recommended in order to determine both the type and degree of HL, as well as the everyday functioning of people with ONIHL. This may help to inform on the specific features required in a HA. This is the method utilised by the National Hearing Service. As such, this is the recommended practice for workers compensation cases.

Treatment for NIHL should be provided to workers who are injured as a result of exposure to occupational noise. Workers need to be made aware of the treatment options available to them, as well as how to access the appropriate services when they need them. Both the physical and emotional well-being of people with ONIHL is the focus of treatment and recovery. It is recommended that HPDs in conjunction with audiological rehabilitation be used to treat ONIHL. Rehabilitation and counselling can be used to promote the use of HAs. However, even with rehabilitation, compliance remains low (Hickson et al., 2013), and auditory training and rehabilitation is still underutilized. To combat this, rehabilitation should focus on improving satisfaction with the performance of HAs in a range of environments that impact daily functioning (e.g., telephone, television, small and large groups).

Treatment outcomes can be measured in relation to workers hearing ability with the use of HPDs, communication ability after rehabilitation, and overall satisfaction with the treatment and management of their HL. Workers level of functioning with the use of HPDs can be assessed through a follow-up audiological assessment to evaluate treatment outcomes.

It is recommended that clinicians account for age when determining the work relatedness of NIHL. As previously mentioned, data from ISO 1999 can be used to estimate the contribution of age on HL (Dobie, 2015; Guest, Boggess, & Attia, 2012). Currently, in NSW workers compensation claims of ONIHL the National Acoustic Laboratories Tables are used to apply an age correction. National Acoustic Laboratories Tables are based on an older version of the ISO 7029 standard. It is recommended that the National Acoustic Laboratories Tables be based on the more current ISO-1999 standards.

Overall Clinical Implications

Diagnosis

Otolaryngologists (ENT doctors) and audiologists who are a member of one of the three Australian professional bodies are the best qualified to diagnose and treat NIHL, and the only ones qualified to provide hearing services under the Australian Governments Hearing Services Program. Audiometry testing is often conducted by audiologists on the behalf of ENTs, however, both audiologists and ENTs assess and diagnose ONIHL.

Current research evidence indicates that conventional PTA remains the 'gold standard' for diagnosing NIHL (Chau, Cho, & Fritz, 2012; Dillion et al., 2016; Fredriksson et al., 2016). Furthermore, the NSW Workers Compensation Guidelines for the Evaluation of Permanent Impairment stipulate that PTA be used for a medico-legal diagnosis of ONIHL. Work Health and Safety Regulation 2017 stipulates that PTA be conducted with workers who are at risk of developing NIHL. Baseline audiometry must be conducted within three months of commencing employment, with follow up Audiometry at least every two years. The addition of otoacoustic emissions in an audiometry test battery to screen at risk populations for sub-clinical NIHL could help identify workers who have mild signs of HL and are at risk of developing ONIHL.

Audiometry is used to establish both the severity and type of HL. Conventional PTA is used to differentiate between the four types of HL: SNHL; conductive hearing loss; mixed hearing loss; and functional hearing loss. When diagnosing NIHL, HL resulting from aging needs to be considered. In NSW, age correction must be applied in the assessment of impairment due to NIHL in order to allow for age related HL in the context of NIHL. The application of these corrections makes it possible to distinguish between NIHL and age related HL with some certainty. However, it is still difficult to distinguish NIHL from age related HL (Ali et al., 2014).

Treatment

The Australian Society of Otolaryngology Head and Neck Surgery guidelines state that HAs are the primary treatment for SNHL. Thus, the best practice treatment for ONIHL is amplification with HPDs, most commonly HAs. This is informed by evidence and scope of practice (Giordano et al., 2008; Hickson et al., 2013). A choice of HPD should be based on the individual workers communication needs and audiology. Conventional HAs are the most common type of HPD used to treat ONIHL. However, people with severe to profound bilateral SNHL who have not been able to establish satisfactory communication with conventional HAs, may be candidates for CI. Audiology rehabilitation is recommended in conjunction with HPD, as well as for people who chose not to use any form of HPD.

The clinical indications for determining the type of HA that is prescribed will depending on: the outcomes of the audiological tests; the number of HAs required (1 or 2); the lifestyle of the hearing impaired person (sedentary / active); the style and preference of HAs; client need for control of HA; ability of client to manage HA; client communication needs and goals; size of ear canal; amount of ear wax in the ear canal; risk factors (e.g., tinnitus); and prognosis (medical conditions that may impact HAs).

The cost of HAs ranges from around $1,500 to $15,000 per pair. The price will vary depending on the type, style, and features of the HA. When assessing the type of HA a person needs, only the features that are needed to promote hearing in the categories where the individual is deficient are needed (e.g., high frequencies).

Conventional HAs may not be effective for people with severe to profound bilateral SNHL. Due to this, people who do not establish satisfactory communication with conventional HAs or have increased communication demands may be candidates for CI. Non-Linguistic Psychoacoustic Measures (e.g., spectral-ripple discrimination test) can help evaluate CI candidacy (Shim et al., 2014).

Outcomes

Outcomes should be measured by assessing workers: hearing function (with preferred HPD); communication ability after rehabilitation; satisfaction with the support they received through counselling; the social and economic impact of NIHL: and overall satisfaction with their level of hearing, communication, and social functioning after treatment.

Results of audiological assessments will help to determine whether the use of HAs is beneficial to the hearing impaired person. Audiological assessments should be made at the beginning and end of a claim. A follow up assessment should be made 12 months after the completion of a claim. Workers self-report of their ability to communicate effectively in their day-to-day environments, along with follow-up audiology will inform on treatment and rehabilitation outcomes. The International Outcome Inventory – Hearing Aids (IOI-HA; Cox et al., 2002) is a validated brief 7-item survey that could be used to assess how satisfied people are with their current HAs. This measure was designed to evaluate the efficacy of HA treatment. It measures: (1) hearing aid usage; (2) benefit; (3) residual activity limitations; (4) satisfaction; (5) residual participation restrictions; (6) impact on others; and (7) quality of life. This survey could be administered and analysed by ENTs, audiologists, audiometrists, or researchers with a working knowledge of audiometry.

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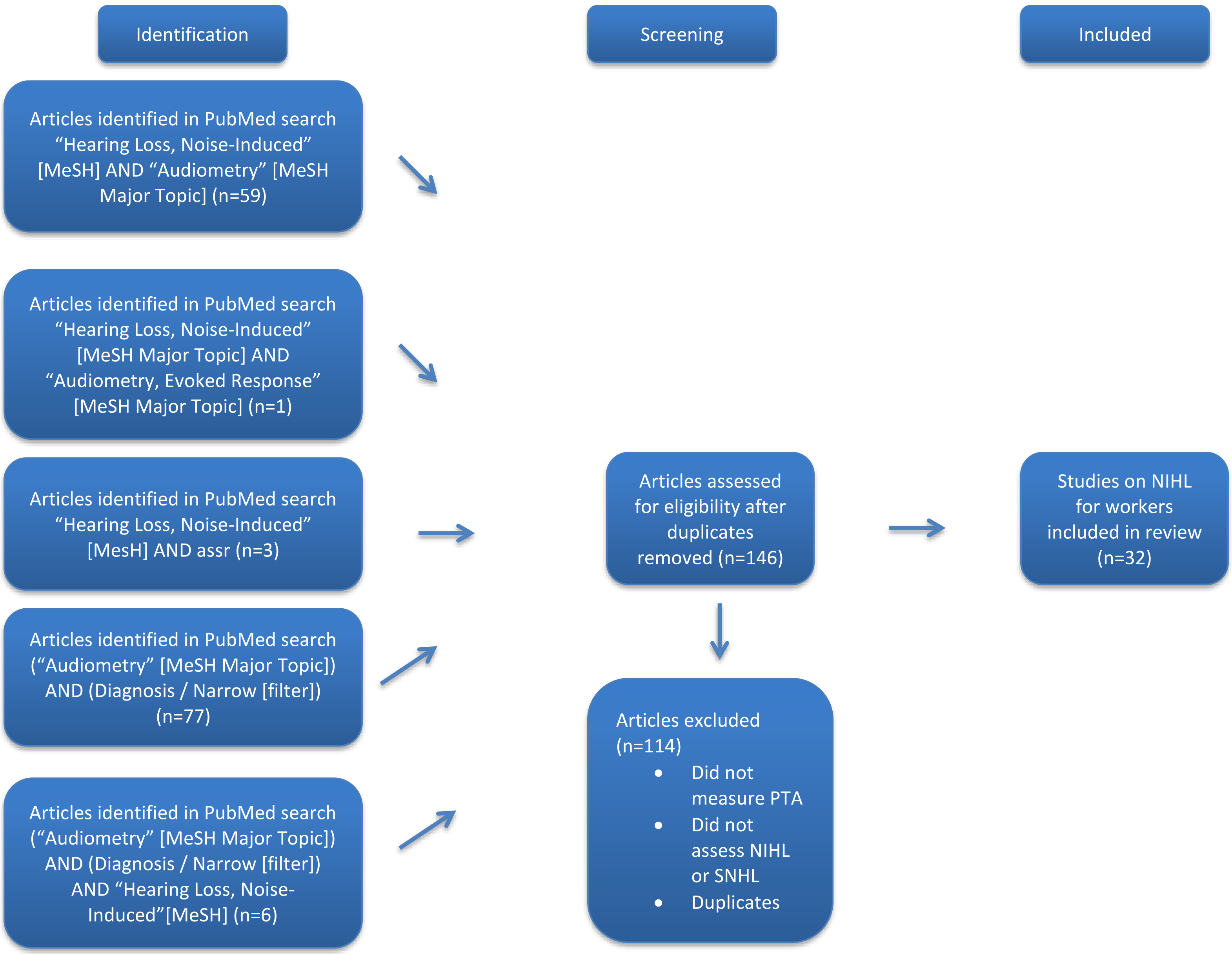
Appendix A: Rapid Reviews Methodology

Occupational Noise Induced Hearing Loss	
Objectives and research questions	Diagnosis • What is the best practice diagnosis for noise induced hearing loss? • Is it possible to differentiate noise induced hearing loss from other types of hearing loss? • Who should make the diagnosis for noise induced hearing loss? • Is this informed by evidence or scope of practice? Treatment • What is the best practice treatment for noise induced hearing loss? • What are the clinical indications for determining the type and cost of hearing aid that is prescribed? Outcomes • How should SIRA measure the outcomes for noise induced hearing loss claims?
Study design	Rapid review
Search strategies	1. PubMed literature search (*see Appendix B*) 2. Search of hearing journals (*see Appendix C*) 3. Additional search: diagnosis, treatment, outcomes
Population	• Adults (male / female) • Occupational noise induced hearing loss workers
Inclusions/ exclusions	• English only • Last 10 years
Summary of the evidence base to inform this priority project	• Was the diagnostic test compared with a reference test that is considered as the 'gold' standard for this diagnostic research? • Was the group of patients that took part in the study representative of patients in our practice? • Was the reference test applied without the researchers having knowledge about the result of the diagnostic test? • Was the test applied again on a second independent group of patients?

Appendix B: Figure 1 PubMed search



Appendix C: Figure 2 Journals search