NOISE-INDUCED HEARING LOSS

NUZHAT HUMA AKHTER
Department of Community Medicine,
Khyber Medical College, Peshawar.

Excessive sound is one of the most common cause of hearing loss. The hazardous effects of noise on hearing have been studied for over a century. Over the past few decades, considerable attention has been given to the mechanisms and features of noise induced hearing loss. The sound levels in urban communities are apparently rising, and the nuisance value of unwanted sound is greatly increased. The most serious pathological effect of noise on man is hearing loss leading to complete deafness. The victim is generally unaware of it in the early stages. Repeated and continuous exposure to noise above 90 dB(A) may result in permanent hearing loss.

The term noise is commonly used to describe sounds that are disagreeable or unpleasant, being produced by acoustic waves of random intensities and frequencies. Noise may be defined as any "audible acoustic energy that adversely affects the physiological or psychological well-being of the people."[1]

Noise pollution is becoming an increasingly serious problem, but recognition of the problem is not universal.[2] Effects of noise exposure have been recognised for centuries but generally ignored.[3] The most unfortunate effect being the damage done to the human ears in the form of hearing loss. The development of hearing loss is sensorineural and characterized by high frequencies (2-2KHz) with a sharp drop at 4 KHz. The type of hearing loss may be a temporary threshold shift (TTS) where the hearing gradually returns to its original value, of permanent threshold (PTS) when the hearing loss does not completely return to its original value.[4] The presence of a PTS shows that an irreversible damage to the peripheral auditory system has taken place. The onset of noise-induced hearing loss is insidious and therefore, it cannot be appreciated in the initial stages, unless detected by audiometry.

A partial impairment of the sense of hearing is described by the "hearing loss". The term "deafness" is reserved for patients with profound or complete hearing loss. The term threshold shift means a change in the threshold at which a person hears a sound, compared with a previously measured level in that person.

The risk of noise-induced hearing loss may be defined as the percentage of workers whose hearing thresholds are raised because of noise, on average, 25 dB at frequencies of 500, 1000 and 2000 Hz.[5] In 1970, Occupational Health Safety and Health Act established occupational noise exposure standards, an employee may receive in a working day.[6] According to this standard 90 dB(A) is the maximum permissible noise level of exposure, without the use of ear protectors for 8 hours per day. In Pakistan, the National Environmental Quality standard for motor vehicle exhaust and noise has been enforced from 29 August, 1993,

according to which noise Emission Standard is 85 dB(A).[7]

Hazardous effects of noise on hearing include adaptation (transitory residual masking), noise-induced temporary threshold shift (NITTS) and noise-induced permanent threshold shift (NIPTS).[8]

ADAPTATION

Adaptation or transient residual masking, is an immediate phenomenon which occurs when a sound is presented to the ear. For fatiguing sounds of up to 90 dB sound pressure level (SPL) the greatest adaptation is produced for an identical test tone of identical frequency. The amount of residual masking that remains after the fatigue tone ceases is proportional to the SPL of the fatigue, but independent of its duration. The recovery is exponential in nature, and for fatigue sounds of up to 70 (SPL), occurs fully within 0.5 second.

NOISE-INDUCED TEMPORARY THRESHOLD SHIFT (NITTS)

Noise-induce temporary threshold shift (NITTS) results from exposure to noise at a moderate level that lasts for a short time (i.e., minutes to hours). As long as the person is not exposed to the noise for too long and the noise is not too loud, the temporary threshold shift is reversible. The degree of temporary threshold shift increases progressively with stimulus, duration and intensity. Recovery is slow and related to fatigue. In general the higher the exposure frequency up to 4-6kHz, the greater the NIPTS produced. Subjective symptoms of a temporary threshold shift include a sense of fullness or ringing in the ears and perception of other's speech as muffled or far away. The person may not recognize the importance of these symptoms because of their transient nature. These symptoms often resolve within 12 to 18 hours after noise exposure. So the person may believe that no permanent harms has been done to this hearing. When a person is first exposed to hazardous noise, the initial change usually observed is an elevation of the threshold of hearing in the higher frequency range. This appears as a steep isolated audiometric dip at about 4 kHz and is called the "acoustic notch". In the early stages of exposure this occurs as a temporary threshold shift, referred to also as noise-induce temporary threshold shift. After a rest period, away from the noise, the hearing usually returns to its former level.

The ears with normal hearing, never previously exposed to prolonged noise, are defined as green ears. The individuals having green ears demonstrate greater noise-induced temporary threshold shift (NITTS) than those whose ears have been exposed to noise for long period of time (ripe ears).

There are some people with tough ears who seem to be able to withstand higher level of exposure better than average, and others with relatively tender ears which are easily damaged.

The recovery of hearing from a pathological temporary threshold shift is small but definite for many days after removal from noise. For practical purposes this is usually ignored because the amount of improvement found after the first day or two is less than the confidence limits of the audiometry used in testing.

NOISE-INDUCED PERMANENT THRESHOLD SHIFT (NIPTS)

Noise-induced permanent threshold shift is defined as the difference for a given test frequency, between the hearing level of an ear that has been exposed to a given noise condition and that of a same-aged otologically normal (or under some circumstances. Otologically similar) ear that has not been exposed to noise (or under some circumstances similarly exposed to noise other than the given noise condition".[9] Incomplete recovery with a residual threshold shift

finally leads to permanent hearing loss. This as an irreversible elevation of the auditory threshold associated with permanent pathological changes in the cochlea.[10]

Permanent hearing loss may interfere with speech reception and thus leads to social isolation. It has been found that in the elderly, hearing impairment is strongly associated with depression.[11] If hearing impairment in the elderly remains untreated, it may interfere with cognitive function.[12] Other noise-related ill effects include disruption of work productivity and sleep[13], physiological and mental disturbances[14] and imbalances within the autonomic nervous system.[15] In most persons, noise-induced hearing loss has an ill-defined onset and is due to prolonged or repeated exposure to noise over months or years.[16] Continuous employment in a potentially noise hazardous environment for 10-15 years is necessary for an initial temporary threshold shift to be established as a noise-induced permanent threshold shift. In a study in traffic police constables, it was found that percentage of abnormal audiograms showing noise-induced hearing loss increase with the increase in duration of noise exposure.[17] In another study, the prevalence of sensori-neural hearing loss was significantly higher among the noise exposed workers, i.e., 83% versus.[13] 7% ($p < 0.01$).[18]

MECHANISM OF NOISE-INDUCED PERMANENT THRESHOLD SHIFT

The average initial change is a temporary threshold shift which imperceptibly merges into permanent threshold shift. Noise-induced hearing loss first becomes evident for frequencies above those important for speech discrimination, and the loss initially escapes notice.[19] The mechanisms involved in permanent loss are direct mechanical destruction, following high intensity noise exposure, and metabolic decompensation with subsequent degeneration of sensory element, following moderate intensity noise exposure. NIPTS usually starts around 4kHz. At first, sensory cells are killed by excessive exposure to noise. These cells do not regenerate, but are replaced by scar tissue.[20] It may be asymptomatic. After a period of few months to a few years of noise exposure, depending upon the intensity, the hearing loss begins to occur but can only be detected by audiometry. The most commonly recognized noise-induced hearing loss is the insidious type caused by chronic noise exposure, manifested as a high frequency sensorineural loss with a notch in the audiogram at the 3 to 6 kHz area.[21] These losses occur in the frequency region around 4 kHz. This abnormality cannot be detected unless periodic hearing assessment is done.[22] Later on it spreads into the lower frequencies, 3 and 2 kHz, and complaints start appearing. The hearing loss at 4 kHz appears to progress at a steady rate for about ten years, and then the rate of progression slows greatly. The effects of continuous exposure are maximal in the region of 2 to 6 kHz, the greater loss occurring at 4 kHz.[23] However, as the years progress the loss spreads into other frequencies and it takes up to thirty years to involve frequencies of 1 kHz and below to any great extent. The rate of progression depends upon the type of noise and individual susceptibility. At this stage, the person becomes aware that he has developed noise induced hearing loss. All individuals exposed to a given noise, do not develop the same degree of hearing loss.[24]

Tinnitus is a fairly constant concomitant of industrial hearing loss and is frequently present for some hours after noise exposure, but it usually disappears. However, after many years of exposure or after intense exposure it may become permanent. In a study done on 94 patients with noise induced hearing loss, it was revealed that tinnitus of a pure tone character was most commonly followed by narrow-band noises and their combination. It was most common at high frequencies. In these cases the most

common subjective symptoms were concentration difficulties, insomnia and decreased speech discrimination.[25] In another study, on 246 workers (492 ears) who underwent otologic and audiologic testing as part of a worker's compensation claim for work-related, noise-induced hearing loss, tinnitus was present in 58% of the patients, but was rarely a major symptom.[26] Tinnitus being a subjective symptoms, is difficult to assess and there is really a confusion to formulate a code to manage and compensate this problem. In industrial workers of Karachi a true assessment of presence of tinnitus in 56% of the workers with noise-induced hearing loss has been claimed.[3]

IMPULSE NOISE (IMPACT NOISE)

Impulse noise is a peculiar type of noise that retains its separate status, both as a physical phenomenon and as an adverse influence, exerted upon human recipients.[27] There are no clear-cut standards of measurement procedures of an impulse noise and threshold level values. Examples of impact noise are hammer sound, rifle shots and fire crackers. Fire crackers may produce sound impulses sometimes reaching peak levels measured at the ear in excess of 160 dB when fired at 2 meter distance. These sound levels are potentially hazardous to the ear.[28] Hearing loss resulting from impact noise is as great or greater than resulting from continuous noise.[29] Steady state and impact noise merge if the time between the impacts is sufficiently short. The impact sounds may vary in intensity and frequency and produce variable effects on hearing. That the duration of exposure to impulse noise determines the intensity of threshold shifts. The impulse noise seemed to produce permanent threshold shifts at 4000 and 6000 Hz after a shorter duration of exposure than continuous steady state noise.[30] The hearing of those who work in noisy environment may be impaired by about 30 dB, such impairment resulting from the raised hearing threshold caused by eight hours exposure to 90-100 dB continuous noise.[31] The corresponding raised threshold caused by eight hours of exposure to impulse noise may be as high as 50 dB.[32] The intermittent exposure to impulse noise in very severe hearing loss in high frequencies but relatively less or no hearing loss in the lower frequencies even after many years of exposure.[33]

ANATOMICAL CORRELATIONS OF NOISE-INDUCED HEARING LOSS

The pathological changes in the hair cells of the cochlea and the amount of the damage correlates both with the intensity of the noise and with the duration of the exposure.[34] The 4-kHz area of basilar membrane which is usually affected by noise lies in the basal turn of the chochlea. This bears the initial impact of sound waves stimulating the inner ear. particularly those of higher frequency which ravel directly across the middle ear space by para-ossicular conduction. At this point, the basilar membrane is more finally fixed, thus subjected to more tension and so more liable to undergo degenerative changes. The morphological changes consist, mainly of hair cells loss, which is more severe in the 9mm to 13 mm region of the cochlear duct.[35] Within the area of maximum hair cell loss, there is a greater loss of outer hair cells than of inner hair cells. The only morphological correlation to the temporary threshold shift is an increase in number and size of liposomes, mainly in the outer hair cells after longer periods of temporary threshold shift.[16]

The positive between outer ear resonant frequency and frequency of maximum hearing loss, emphasizes the role that external ear properties play in the development of the 4-kHz audiometric notch.[36] Hair cells are certainly damaged by exposure to excessive sound. Mild sound exposure produces minor cilial changes.[37] The outer hair cells are much more susceptible to

trauma from noise and they become fused and/or disappear. There is significant evidence of damage to the dendritic nerve endings surrounding inner and outer hair cells but these changes might be reversible. The damage to the peripheral cochlear organs was found in school children, exposed to aircraft noise.[38] In another study, damage of both peripheral cochlear organs and the central auditory pathway by high-frequency aircraft noise exposure was confirmed.[39]

PHYSIOLOGICAL ASPECTS OF NOISE-INDUCED HEARING LOSS

Summation of temporary threshold shift curves resulting from several pure tones recorded in the same diagram, occurs at or above 4 kHz. The sensitivity of the ear, however, decreases steeply above this frequency. The maximum effect, therefore, occurs exactly in the area around 4 kHz. Because of the important role of the hair cells in hearing, these cells are possible site for the loss of cochlear sensitivity that follows acoustic over-stimulation.[40] The functional changes in the hair cells explaining origin of noise-induced hearing loss. Both types of hair cells showed a reduction in amplitude and an increase in the symmetry of their acoustically receptor potential. Moreover, the outer hair cells also suffered a sustained depolarization of the membrane potential. Thus the modified function of the hair cells, after acoustic over-stimulation, may determine the extent of noise-induced hearing loss.

PREVENTION

Noise-induced hearing loss is entirely preventable but totally incurable problem.[41] the amount of hearing loss due to noise can be decreased by reducing the noise produced by machinery and equipment used by the general public, attenuating noise on its path to the ear and providing effective education about the danger to hearing caused by loud noise. Persons working in noisy environments should wear hearing protection devices as often as possible and should not engage themselves in other noisy hobbies. Inexpensive foam earplugs can be comfortably used for prolonged periods and offer adequate protection (upto 25 dB).[42] In a study it has been shown that oral magnesium administration may serve as a natural prophylactic agent for preventing noise-induced permanent threshold shift in subjects exposed to noise. This is especially useful where the use of mechanical hearing protectors is limited or not applicable.[43]

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