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Classification of Hearing Loss

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<http://dx.doi.org/10.5772/61835>

Abstract

Hearing loss is the partial or total inability to hear sound in one or both ears. People with hearing loss make up a significant 5.3% of the world's population. The audiogram is an important tool used to determine the degree and type of hearing loss. This chapter presents hearing loss classification, which can aid in clinical diagnosis and help in finding appropriate therapeutic management. Hearing loss is classified based on ear anatomy, type of hearing loss, degree of the disease, and configuration of the audiogram. When the hearing loss is fully characterized, appropriate medical intervention can be assigned.

Keywords: Hearing loss, Audiometry, Conductive hearing loss, Sensorineural hearing loss

1. Introduction

Hearing is a very important sensation for human beings. It helps to understand the surrounding environment and can alert of any coming danger around us. Hearing is an essential means of communication. Hearing loss is the impairment of the ability to hear sound. The most quiet sounds that people can hear are between 25 and 40 decibel (dB). Anybody who suffers from mild hearing loss has difficulty keeping up with normal conversations. People who suffer from profound hearing loss are deaf and can hear nothing at all. Hearing loss can impact learning and development in children, including speech and language. In adults, hearing loss can greatly affect the overall quality of life, since it impacts social interaction and general well-being. Consequently, hearing loss can cause many difficulties in various aspects of life. Hearing loss can occur in different types and degrees of severity. In normal hearing, sound vibrations pass from the outer ear through the middle ear to the inner ear. In conductive hearing loss (CHL), vibrations cannot pass from the outer ear to the inner ear. In sensorineural hearing loss (SNHL), there is a dysfunction in the inner ear. In mixed hearing loss, there is a combination of conductive and sensorineural components. At the end of the inner ear (cochlea), thousands

of auditory nerve fibers detect the high and low sound frequencies and transmit action potentials to the brain, which interprets the signal as sound. Repeated exposure to loud noise can damage the sound-sensitive hair cells in the inner ear, so it is important to protect hearing from harmful environments.

2. Hearing loss

2.1. Defining hearing loss, its prevalence, and incidence

Hearing loss, the most common form of human sensory deficit, is the partial or total inability to hear sound in one or both ears. It may be a **sudden** or a **progressive** impairment that gradually gets worse over time. Depending on the cause, it can be mild or severe, temporary or permanent. It may be a **bilateral** loss occurring in both ears or **unilateral**. Hearing loss may be **fluctuating**, that is, varying over time—improving at times and getting worse at other times. In other cases, hearing loss is **stable**, not changing at all with time. Hearing loss is caused by many factors, including genetics, age, exposure to noise, illness, chemicals, and physical trauma. Hearing loss may affect all ages, delaying speech and learning in children, and causing social and vocational problems for adults. According to the World Health Organization (WHO), there are 360 million persons in the world with hearing loss (5.3% of the world's population), and 32 million of whom are children [1]. The prevalence of hearing loss is increasing in adolescents and young adults and is associated with exposure to loud music. As for the aged, WHO reports that one-third of people above 65 years are living with disabling hearing loss [1]. Age-related hearing loss, **Presbycusis**, compromises the ability to discriminate sounds in environments with background noise. With the expected increase of 18–50% of the aging population in the coming years, the number of people with hearing loss will consequently grow [2]. Luckily, through early diagnosis and interventions, the majority of hearing loss cases are treatable. Understanding hearing loss and its classification is thus essential in improving the screening methods, preventive approaches, and in the management of the disease. A clear and concise description of the classification system for hearing loss based on the current state of scientific knowledge is important not only for clinical diagnosis and therapeutic management, but also for the use in medical research and education. In addition, a clear-cut explanation of the disease can aid patients who will themselves benefit from a better understanding of their hearing loss.

2.2. Understanding the audiogram

Hearing is examined by making the subject listen to a number of different pure tone signals through a pair of headphones or earplugs to record air conduction. An audiometer examines hearing ability by testing the threshold of hearing a sound signal at various frequencies (pitch, in cycles per second or Hz). Hearing threshold may be defined as how soft a sound may get before it becomes inaudible. Thresholds are measured in dB; the normal threshold is between 0 and 25 dB for adults and between 0 and 15 dB for children. Threshold is recorded on a graph known as the audiogram. The audiogram presents the sound frequency (ranging from low to high frequency) on the horizontal axis and sound intensity or loudness in dB on the vertical

axis. Right ear thresholds are recorded as red circles on the audiogram while the left ear thresholds are recorded as blue Xs. Figure 1 shows a typical audiogram with normal air conduction. A bone conduction test may be performed by bypassing the outer ear and the middle ear (also known as the air conductive pathway) to find the threshold when sound is delivered directly to the cochlea. This is done by placing a bone conductor, which sends tiny vibrations to the inner ear, on the mastoid process. A comparison between results from the air conduction test (that uses tone as stimulus) and the bone conduction test provides a better indication of whether hearing loss is due to conduction deafness or nerve deafness.

Normal Audiogram

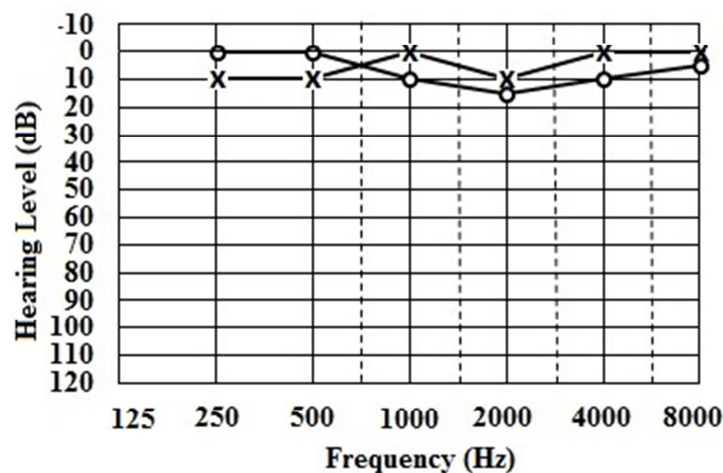


Figure 1. A typical audiogram with normal air conduction for both ears. Symbols: X, left ear air conduction; O, right ear air conduction.

2.3. Classifying hearing loss according to

2.3.1. Anatomy of the ear

An examination with attention to the anatomy of the ear is critical for establishing a hearing loss diagnosis. The auditory system is typically divided into three main sections: the outer, middle, and inner ears (Figure 2). **The outer ear** receives sound waves from the environment. The auricle captures sound and directs it into the external auditory canal (EAC) that ends at a thin diaphragm called the tympanum or ear drum. Obstruction of the EAC with ear wax or a foreign body, and inflammation of the canal, the auricle, or both (otitis externa) may produce hearing loss. Atresia, the congenital absence of the external ear canal and microtia, a congenital deformity where the pinna is underdeveloped, also cause hearing loss. Sound travels **the middle ear** as vibrations of three connected ossicles (malleus, incus, and stapes). Increase and decrease in sound-induced air pressure push and pull the tympanum, resulting in a mechanical response. The base of the first ossicle (the malleus) is attached to the tympanic membrane, while the last of the ossicles (the stapes) inserts in an opening called the oval window in the

bony inner ear, the cochlea. The vibration of the incus drives the stapes deeper into the oval window and retracts it, pushing and pulling cyclically upon the liquid in the inner ear. The vibrating ossicles thus allow for the delivery of sound from the air-filled outer ear to the fluid-filled inner ear. Compromise of the middle ear's anatomy may lead to hearing loss. For example, bone growth in the ligamentous attachments of the ossicles can immobilize the ossicles and lead to severe deafness in a condition termed otosclerosis. Also of significance in the middle ear, attached to the stapes, is the stapedius muscle. This muscle contracts in response to loud sounds, thereby decreasing sound transmission to the inner ear and protecting it from acoustic insults. The cyclic motion created by the stapes displaces a liquid mass in **the inner ear**, which results in a traveling oscillating wave along the basilar membrane. The basilar membrane is elastic at the apex of the cochlea where it is most sensitive to low frequencies. On the other hand, the basilar membrane is stiff at the base of the cochlea and responds to high frequencies. Hair cells along the basilar membrane detect the frequency of the stimulus. The traveling wave pushes hair cells, depolarizing them and stimulating the afferent nerve fibers they are connected to, thereby transmitting the sound signal through the auditory (acoustic) nerve to the brain.

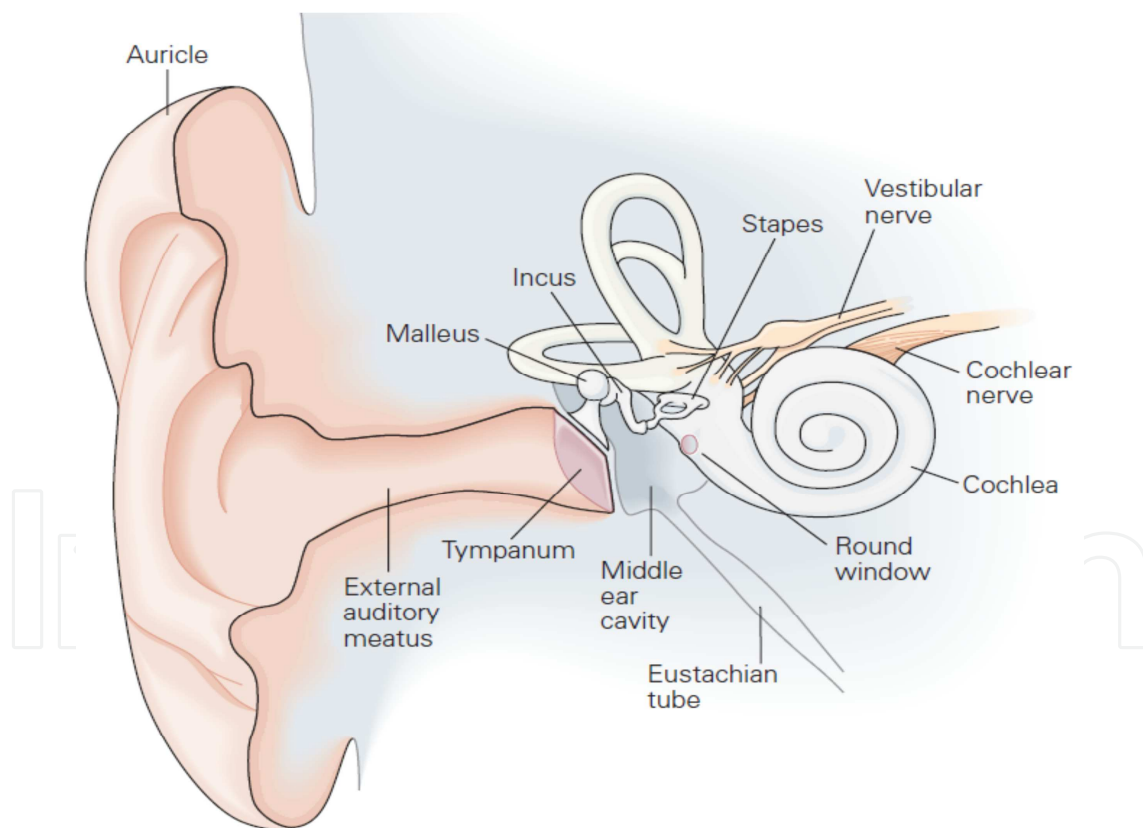


Figure 2. The structure of the human ear. The external ear, especially the prominent auricle, focuses sound into the external auditory meatus. Alternating increases and decreases in air pressure vibrate the tympanum. These vibrations are conveyed across the air-filled middle ear by three tiny, linked bones: the malleus, the incus, and the stapes. Vibration of the stapes stimulates the cochlea, the hearing organ of the inner ear. (Source [3]: Kandel et al. 2013 Principles of Neural Science. 5th ed.).

2.3.2. Type of hearing loss

Functionally, the human ear can be divided into two major divisions, the conductive division, associated with the areas responsible for air conduction (the outer ear and the middle ear) and the sensorineural division associated with the inner ear. Accordingly, the three main types of hearing loss are classified as conductive, sensorineural, and mixed hearing losses.

1. CHL is a type of hearing loss characterized by having better hearing thresholds for bone-conducted signals compared with air-conducted signals. CHL is usually associated with dysfunction located in the outer and/or middle ear while having a normal inner ear function. In CHL, the audiogram typically shows normal bone conduction (0–25 dB) and abnormal air conduction threshold levels (higher than 25 dB). According to the American Speech-Language-Hearing Association, a difference greater than 10 dB is considered a significant air–bone gap and requires the use of masking to eliminate a response from the ear not being tested, hence obtaining true thresholds from the test ear [4]. CHL can affect all frequency ranges. However, the low (250–500 Hz) or low and mid-range (250 Hz–2 kHz) frequencies are most commonly affected (Figure 3). The worst scenario of CHL is a loss of 60 dB or more. In the case of a total absence of the conductive function of the ear, sound waves can reach the cochlea through skull vibration and fluid movement. Most of the CHL cases are treatable with medication, surgery, amplification, assistive devices, or a combination of these. A common cause of CHL is the absence or malformation of the outer ear, ear canal, or middle ear structures. Atresia and microtia are such examples. Conductive pathologies include otosclerosis and cholesteotoma. The latter being a cystic mass of epithelial cells and cholesterol that occlude the middle ear and produce enzymes that may destroy adjacent bones. Tympanosclerosis, a consequence of chronic otitis media, is a condition of the middle ear cleft in which there are calcareous deposits in the tympanic membrane and the ossicular chain leading to CHL due to stiffness and reduced mobility. Other common causes of CHL include occlusion of the ear canal due to wax buildup or by a foreign object, perforated or scarred eardrum, outer ear (otitis externa) inflammation, or inner ear (otitis media) inflammation, trauma which causes injury to the tympanic membrane and/or ossicles, fluid accumulation, allergies, dysfunction of the Eustachian tube that normally drains fluid from the ear to the back of the throat, and benign tumors.
2. SNHL is a hearing loss that occurs as a result of damage in the cochlea or beyond, that is, either along the 8th cranial nerve or in the brain. SNHL can cause complete loss of hearing, despite the outer ear and middle ear being normal. Individuals with SNHL demonstrate similar air and bone conduction thresholds. The sensory component is usually due to the damage to the organ of Corti or to an inability of hair cells to stimulate the auditory nerve. The neural component refers to when damage is proximal to the cochlea and auditory nerve; the term retrocochlear damage is also used. SNHL may be the result of perinatal infections such as rubella, herpes, toxoplasmosis, syphilis, and cytomegalovirus. Birth complications associated with SNHL include asphyxia and low birth weight. Later onset causes of SNHL include infections such as meningitis, labyrinthitis, mumps, scarlet fever, and measles. Long exposure to loud noise induces SNHL by direct mechanical damage

Conductive Hearing Loss

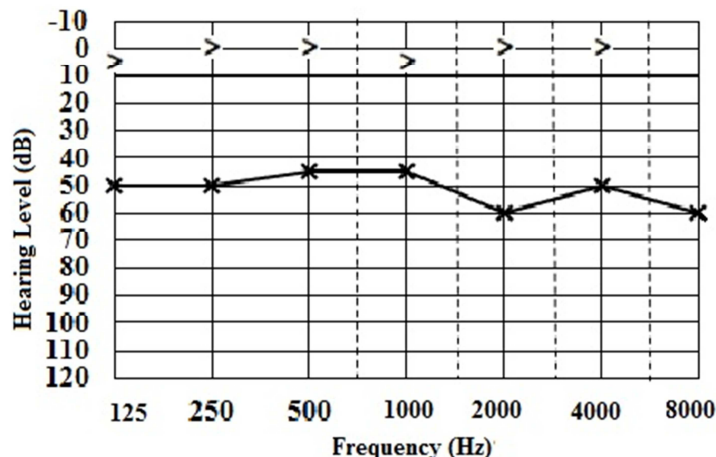


Figure 3. An audiogram with CHL for the left ear. The bone conduction is within normal range (0–25 dB) and the air conduction is in moderate–moderately severe range (moderate range: 41–55 dB, moderately severe:56–70 dB). Symbols: X, left ear air conduction; >, left ear bone conduction.

of inner ear structures. The US Occupational Safety and Health Administration require ear protection in the work area when an average exposure of 85 dB is reached. Severe SNHL may also occur after sudden exposure to a loud noise at 120–155 dB, for example from explosions, fireworks, gunfire, and music concerts. Other causes of SNHL include malformation of the inner ear, aging, Meniere’s disease, drug-induced ototoxicity, and tumors such as acoustic neuroma. SNHL often cannot be reversed. Figure 4 shows an audiogram with SNHL.

Sensorineural Hearing Loss

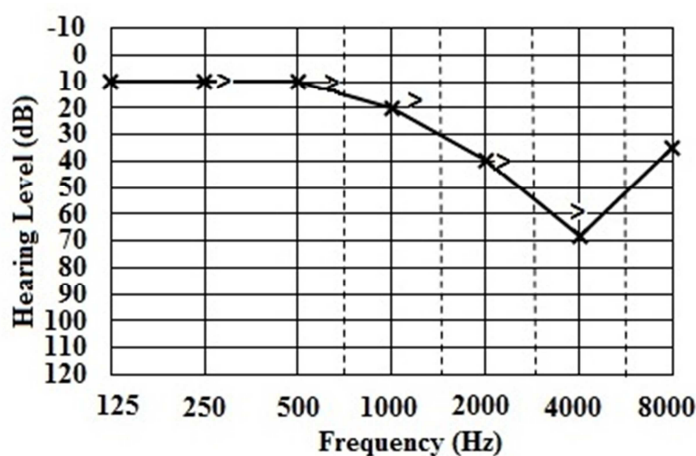


Figure 4. An audiogram with SNHL at high frequencies for the left ear. Both air conduction and bone conduction of high frequencies are in the mild (26–40 dB) to moderate range (41–55 dB) of hearing loss. Symbols: X, left ear air conduction; >, left ear bone conduction.

- Mixed hearing loss is a type of hearing loss that has a combination of conductive and sensorineural damage in the same ear. Cases where both an air–bone gap greater than 10 dB and an elevated bone conduction threshold are observed suggest a mixed hearing loss. While the conductive component may be treated, the sensorineural component is more of a challenge. Figure 5 shows an audiogram with mixed hearing loss.

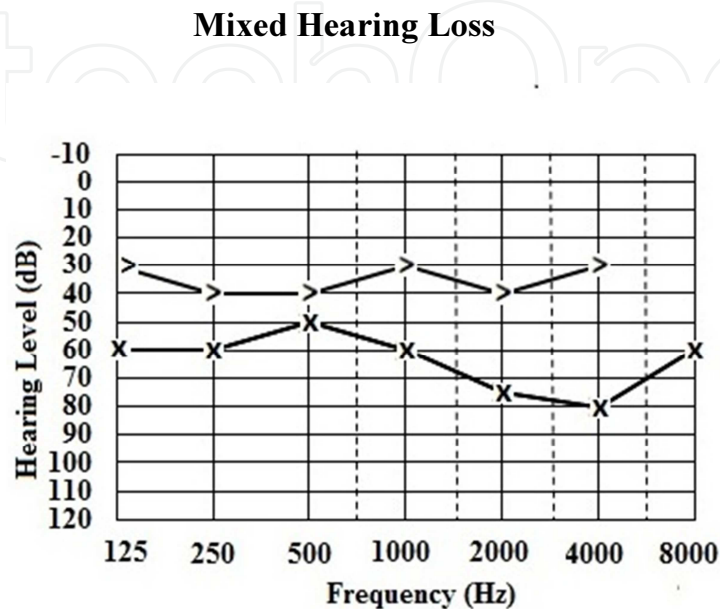


Figure 5. An audiogram with mixed hearing loss for the left ear. Both air conduction and bone conduction are in the abnormal range, with the air–bone gap generally greater than 10 dB. Symbols: X, left ear air conduction; >, left ear bone conduction.

2.3.3. Degree of hearing loss

Hearing loss can be classified according to the severity or degree of the disease. Hearing losses between 26 and 40 dB are considered mild, 41 and 55 dB moderate, 56 and 70 dB moderately severe, 71 and 90 dB severe, and greater than 91 dB profound (Table 1) [5, 6]. Severity of hearing loss is based on thresholds at individual frequencies. Once the type and degree of loss are established, an appropriate intervention may be assigned. This may include hearing aids, aural rehabilitation, cochlear implants, medical intervention, or surgery.

2.3.4. Configuration of hearing loss

Hearing losses may be categorized according to the audiometric configuration, that is, the shape or pattern of the audiogram across the frequency spectrum [7]. The configuration of an audiogram will tell you which sounds are best heard. A hearing loss that is more or less the same at all frequencies is depicted as a straight horizontal line on the audiogram and is thus appropriately called a **flat configuration**. In this configuration, thresholds across frequencies do not vary more than 20 dB from each other. In other words, a person with this type of loss needs the same amount of loudness to hear a sound regardless of the pitch. A person with a

Degree of hearing loss	Hearing threshold (dB HL)
Normal hearing	-10-15
Slight	16-25
Mild	26-40
Moderate	41-55
Moderately severe	56-70
Severe	71-90
Profound	>91

Table 1. Degree of hearing loss based on the hearing threshold. Source [5]: Clark JG: Uses and abuses of hearing loss classification. ASHA. 1981, 23:493-500.

sloping configuration has little or no hearing loss at low frequencies, severe loss at mid-frequency range, and profound loss at the higher frequencies. Ski-slope loss is another name for this configuration because the audiogram looks much like a ski slope with the top of the hill on the left and the slope dropping down to the right. Inversely, a **rising configuration** indicates that high-frequency sounds can be better heard than low-frequency sounds. This is a rare type of audiogram, an extreme example would be a person who is unable to hear thunder or explosive noise but can hear whispers across a room. Someone suffering from **cookie-bite or U-shaped configuration** hearing loss has one or more adjacent thresholds between 500 and 4,000 Hz ≥ 20 dB and so is likely to experience difficulty in hearing mid-frequency sounds, while maintaining the ability to hear high- and low-frequency sounds. Usually it is genetic; this type of hearing loss may progress over time. A **noise-notched configuration** indicates a hearing loss mostly between 3 and 6 kHz, while lower and higher frequencies are not affected. This configuration is observed in hearing loss due to noise exposure since sensory cells in the cochlea are more prone to noise damage in the 3-6 kHz frequency range than lower and higher frequencies. **High-frequency configuration** would show good hearing in the low frequencies and poor hearing in the high frequencies. Figure 6 shows the different configurations of hearing loss.

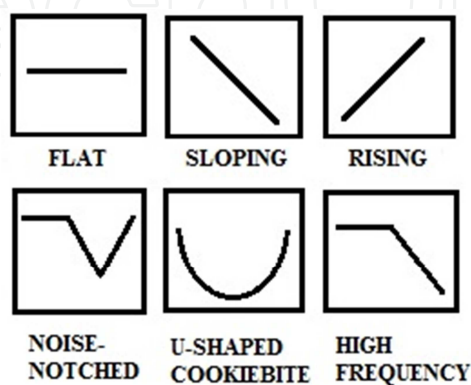


Figure 6. Hearing loss configurations.

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