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Otitis Media: Parental Perspectives and Support Needs

Jordan Marie Johnson
University of Northern Colorado

UNIVERSITY OF NORTHERN COLORADO

Greeley, Colorado

The Graduate School

OTITIS MEDIA: PARENT PERSPECTIVES AND SUPPORT NEEDS

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Jordan Marie Johnson

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Has been approved as meeting the requirement for the Degree of Doctor of Audiology in the College of Natural and Health Sciences, Department of Communication Sciences and Disorders, Program of Audiology.

Accepted by the Doctoral Scholarly Project Research Committee:

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Deanna K. Meinke, Ph.D., Co-Research Advisor

____

Diane Erdbruegger, Au.D., Committee Member

____

Erinn Jimmerson, Au.D., Committee Member

ABSTRACT

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Otitis media (OM) is an infection located within the middle ear space of the auditory system and is the most common cause of hearing loss in children. Hearing loss is the disruption of the perception of an auditory signal and is further classified as conductive, sensorineural, or conductive. The effect of hearing loss can also depend on the severity, time of onset, stability, and etiology. Impairment in auditory function is linked with poorer speech and language development, educational tasks, psychosocial skills, and quality of life. Therefore, identification of hearing loss in children should be done in a timely manner to minimize the impact to which infrastructure is in place to guide clinicians. Otitis media has many presentations and is described in many ways. Inflammation and infection can occur with or without effusion (OME). Effusion is described as fluid presence in the air-filled middle ear space. Chronic (COME) cases last longer than 3 months while chronic suppurative (CSOM) describes chronic inflammation and mastoid mucus with related tympanic membrane damage and/or discharge. An infection characterized by fast onset is considered acute while recurrent acute (RAOM) infections exist with increased frequency of infections. The increased prevalence of OM in children can be attributed to anatomical differences between children and adults accounts for increased prevalence in children in comparison to adult patients. Risk factors include exposure to other airborne viruses/bacteria, cigarette smoke, lack of breastfeeding, having siblings, attending daycare, lower socioeconomic status, facial anomalies, etc. These factors, early identification of

otitis media, along with parental understanding and needs will be highlighted to identify how to better support those experiencing OM, especially in the context of professional clinical care guidelines.

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LIST OF ABBREVIATIONS

AAA:	American Academy of Audiology
AAFP:	American Academy of Family Physicians (AAFP)
AAO:	American Academy of Otolaryngology
AAO-HNS:	American Academy of Otolaryngology-Head and Neck Surgery
AAP:	American Academy of Pediatrics
AOM:	Acute otitis media
APD:	Auditory processing disorder
CANS:	Central auditory nervous system
CHL:	Conductive hearing loss
CMV:	Cytomegalovirus
CSOM:	Chronic suppurative otitis media
COME:	Chronic otitis media with effusion
EAM:	External auditory meatus
ET:	Eustachian tube
ETD:	Eustachian tube dysfunction
ICD:	International Classification of Disease
JCIH:	Joint Committee on Infant Hearing
ME:	Middle ear
MEE:	Middle ear effusion
MHL:	Mixed hearing loss

NBHS:	Newborn hearing screening
OM:	Otitis media
OME:	Otitis media with effusion
RAOM:	Recurrent acute otitis media
SNHL:	Sensorineural hearing loss
TM:	Tympanic membrane
TT:	Tympanostomy tube
WHO:	World Health Organization

CHAPTER I

REVIEW OF THE LITERATURE

Understanding ear anatomy and physiology is needed to better understand otitis media as a middle ear disorder. Otitis media refers to an infection and inflammation within the middle ear space. Prevalent amongst young children clinical management is a shared responsibility between parents and physicians (pediatric, family practice, and otolaryngology). This research delves into the dynamic landscapes of otitis media through an exploration of contributing factors, risk factors, manifestations, and impact on patients and family members. Clinical guidelines inform the management of children with otitis media, and if the disorder becomes chronic, especially during critical speech-language development, audiologists and speech-language pathologists may also become involved in the child's care. Ultimately, professionals should strive to consider parent perspectives when coordinating care and treatment approaches.

Anatomy and Physiology of the Auditory System

The auditory system is a complex biomechanical system, which is the sensory system responsible for sound perception. Sound perception is accomplished by ear structures that collect and transduce vibrational pressure changes in the air originating from a sound source. Those sounds are funneled through the outer ear, transmitted through the middle ear as mechanical energy, and eventually transduced into an electrical signal within the inner ear transmitted to neural structures to be further processed along the central auditory pathways (Schow et al., 2021)

The outer ear portion includes the auricle (pinna) and the external auditory canal, terminating at the tympanic membrane. The middle ear is an air-filled cavity housing the tympanic membrane, ossicular chain, and Eustachian tube. When air vibrations impinge upon the tympanic membrane, the sound is transformed into mechanical energy that sets three ossicles (malleolus, incus, and stapes) into motion. The stapes footplate is within the oval window of the inner ear, where mechanical vibrations are transformed into hydromechanical energy via fluids within the inner ear. The inner ear is made up of a bony labyrinth with two functional portions further split into the cochlea and the vestibular system. The cochlea is a spiral cavity separated into three fluid-filled compartments or Scala. In the medial Scala is the organ of Corti containing tiny hair cells, the sensory receptors of the ear. The organ of Corti sits atop the basilar membrane, responsible for moving in response to the hydromechanical energy received. Occurring when the cochlear fluid is displaced via the stapes pushing in and out of the oval window. This motion sets up fluid motion within the cochlea that leads to the shearing of stereocilia on top of the hair cells. This causes a change in cochlear potentials when ion channels are opened which leads to depolarization of the hair cell and firing of auditory neurons that connect to the base of hair cells. When an action potential is fired it will travel along the VIIIth cranial nerve and central auditory nervous system (CANS), including neural fibers and nuclei within the brainstem, midbrain, and cortex. Central auditory information is integrated with sensory input from both cochleae. The CANS allows individuals to process auditory signals in terms of sound detection, sound recognition, localization, and pattern recognition (Aristidou & Hohman, 2023). The structure and function of each part of the are described in more detail subsequently.

Outer Ear

Pinna and external auditory meatus

The outer ear begins at the pinna. The pinna is composed of cartilage, muscles, and ligaments on either side of the head which matures during early childhood until about age 11 for girls and 12 for boys (Kalcioglu et al., 2003). The pinna functions by collecting air-borne sound vibrations and funneling the sound energy from the outside environment into the external auditory meatus (EAM). The EAM can vary slightly in orientation but tends to have a slight bend in shape upon maturation. Two divisions of the EAM exist, an outer cartilaginous portion, and an inner osseous portion (Seikel et al., 2021). Cilia line the canal wall and trap any debris that enters the area. Apocrine and Sebaceous glands contribute to cerumen production within the system also working to capture any debris in the area. Epithelial migration is a biological process in which epithelial cells lining the ear canal move outwards as a self-cleaning mechanism (Cecire & Gibson, 1991). This process within the external auditory canal allows for the natural movement of cerumen laterally towards the external acoustic meatus but in some cases, the cerumen may occlude the canal. The inner portion of the EAM terminates at the tympanic membrane (TM). This creates a tube closed at one end and open at the other and is termed a "quarter-wave resonator" meaning within specific frequency ranges sound signals will be amplified due to the ear canal properties. Ear canal resonance is larger for younger children because the system is more-mass dominated initially compared to adults (Seikel et al., 2021).

Middle Ear

Tympanic membrane

Volandri et al. (2011) described an adult TM to be comprised of three layers with slightly varying structures allowing varied movement in response to acoustical energy changes based on the location of primary impact. Therefore, it is termed a tri-laminar membrane with an outer epidermal layer continuous with the canal's epidermis serving as a boundary to the middle ear space, an intermediate fibrous layer, and an inner mucosal epithelial layer serving as a boundary in the middle ear. The tympanic sulcus on the temporal bone forms a ridge in which the TM is seated. The annulus, or outer ring of the TM, is thickened to fill this groove forming a boundary to the middle ear space (Volandri et al., 2011).

On average, the TM sits at an angle of 140 degrees between the superior and posterior walls of the canal and a 30-degree angle between the inferior and anterior walls (Ferrazzini, 2003). This angled orientation optimizes the amount of sound energy transmitted from any given sound source through the middle ear system. Given the tri-laminar structure and the connection to the malleus, the TM has a concave-like appearance. The most depressed portion of the TM is at the point of attachment to the manubrium (handle) of the malleus, and the portion of the TM where maximum depression occurs is the umbo. Thickness distribution across the TM varies depending on the specimen indicating a non-uniform thickness distribution with the thinnest area existing centrally between the umbo and manubrium and thickest in the pars tensa peripheral rim, surrounding the umbo, and thickening was also observed in the anterior-inferior portion of the TM (Van der Jeught et al., 2013). The thickness of the TM directly impacts the stiffness and mass of the system ultimately affecting the displacement of the ossicular chain and transmission of sound (S.-I. Chen et al., 2013).

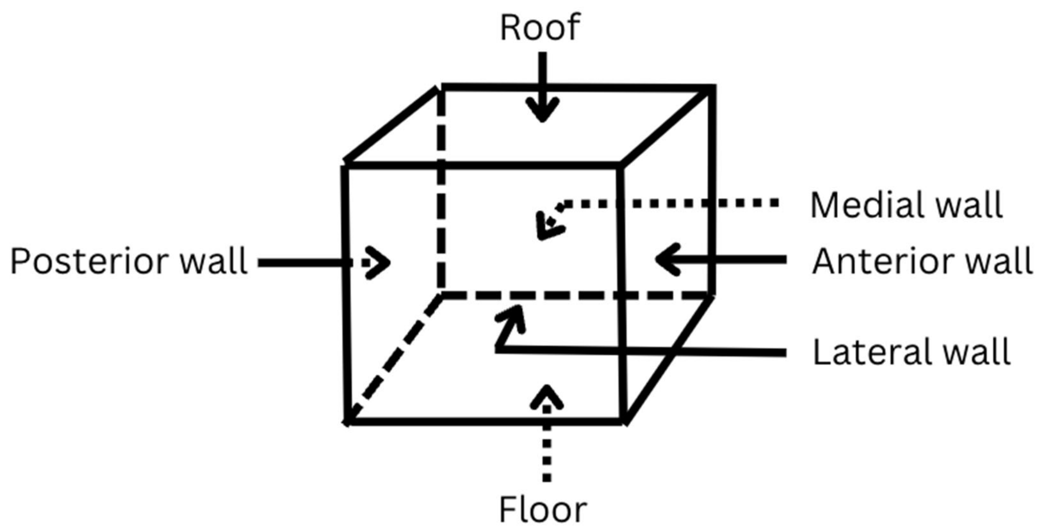
In 2011 Volandri et al. modeled middle ear mechanics based on information within the literature currently available. In their detailed description of the biomechanics of the TM, the pars tensa comprises a larger region of the TM composed of collagen resulting in the area being stiffer and pars flaccida which is the superior region, compromising a smaller portion of the TM, with fibers distributed more sparsely resulting in more elastic characteristics. The umbo is defined as the location in which the malleus of the ossicular chain attaches to the TM and can often be visualized via otoscopy. This is the point of sound transduction as sound energy within the canal reaches the TM where the vibrations are transmitted to the middle ear and passed along through the malleus inducing ossicular chain mechanical vibration. If stiffness in this system were to be increased sound transmission would decrease as a result (Volandri et al., 2011).

Middle Ear Air-Filled Cavity

Deep within the petrous portion of the temporal bone, an air-filled space houses the middle ear anatomy (Seikel et al., 2021). This space is often conceptualized as a box bordered laterally by the TM and medially by the promontory of the inner ear (Figure 1). The superior boundary is formed by the tegmen tympani, a thin layer of bone separating the middle ear space from the middle cranial fossa. Another thin layer of bone comprised of the tympanic plate of the temporal bone forms the inferior boundary, referred to as the “floor”. The anterior wall is formed of a thin layer of bone creating separation from the internal carotid artery and contains the eustachian tube and tensor tympani muscle. This wall contains an opening to the Eustachian tube which is narrow and connects the middle ear cavity and throat. The Eustachian tube allows for the equalization of air pressure between the throat and middle ear space. An attachment site for the tensor tympani is also formed and reaches to the head of the malleus ossicle. The internal carotid plexus has a branch running through the anterior wall innervating the sympathetic plexus associated with the internal carotid artery. The posterior wall of the middle ear houses a portion of the chorda tympani, a branch of the facial nerve, running through the middle ear space and exiting through the anterior wall. The medial wall houses the promontory, a protrusion of the cochlea’s final turn into the middle ear space, and the tympanic plexus forms the tympanic branch of the glossopharyngeal nerve. The oval and round windows are membrane-covered openings that connect the middle and inner ear portions. The oval window serves as a connection point for the stapedial footplate where mechanical energy will be transferred into the fluid-filled space of the inner ear.

Figure 1

Middle Ear Space



Ossicular chain

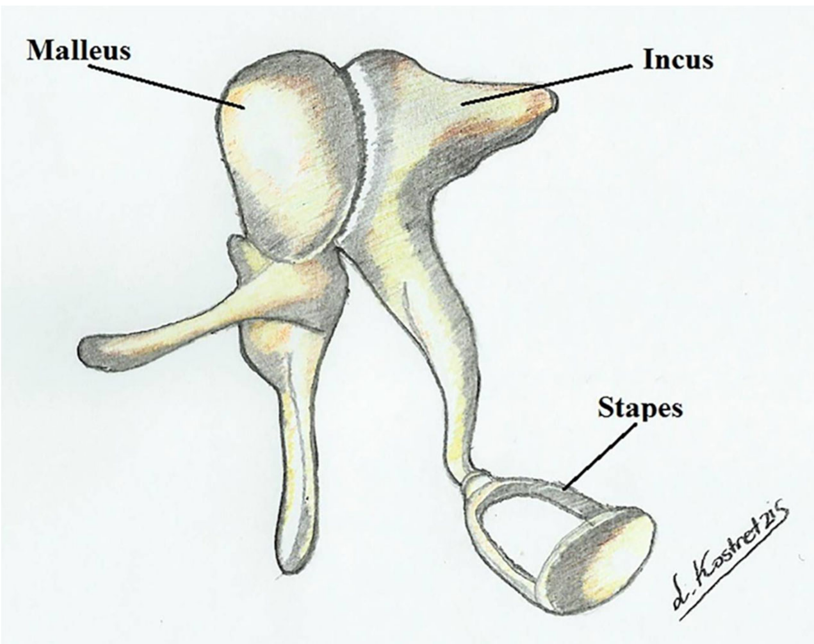
The ossicular chain within the middle ear is organized in a lever-like arrangement and is comprised of the three smallest bones in the body, the malleus, the incus, and the stapes (Figure 2) (Noussios et al., 2016). The ossicles are interconnected by a ligament array and function to transfer sound energy across the middle ear space. The malleus attaches to the umbo of the TM at the handle, also called the manubrium. At the anterior end of the manubrium is the head of the malleus which is attached to the incus. It is important to note that the malleus is longer than the incus in length which creates an efficient lever system between the two to transfer sound energy. The incus formed by a body, two crura, and a process terminating at a rounded projection termed the lenticular process attaches to the head of the stapes. The smallest bone in the human body, the stapes, has two cura extending medially from the neck and attaching to the stapes footplate. The stapes footplate serves as the attachment site to the oval window (Seikel et al., 2021).

This anatomical system functions to successfully transmit, amplify, and protect from high-level sound (Seikel et al., 2021). When vibrations are received from the TM and the pressure changes are transferred to the manubrium of the malleus, motion is initiated across the ossicular chain. The motion leads to the stapes footplate pressing into the oval window of the inner ear transferring the mechanical energy from the TM and ossicles into hydromechanical pressure waves within fluid-filled cochlea.

Impedance refers to the opposition of the flow of energy in which mediums may demonstrate variation in impedance values. Air has a lower impedance than that of a fluid so when the stapes footplate presses on the oval window some energy is naturally lost due to the mismatch in impedance between air and inner ear fluids. The amount of energy lost, or reflected, is estimated to be around 31 to 37 dB which is compensated for by the middle ear mechanisms (Seikel et al., 2021,). However, the middle ear has characteristics that allow this mismatch of energy flow to be compensated for by amplifying the sound vibrations that are received at the TM. Often referred to as the "impedance matching mechanisms", these include the concavity of the TM, lever action of the ossicular chain, and the surface area ratio of approximately 17 to 1 between the larger TM and the smaller stapes footplate. Given the importance of a properly functioning middle ear system to overcome the difference in impedance, any disruption in the ossicular chain results in conductive hearing loss. Decreased sound transmission due to perforations in the TM, disarticulated ossicles, or blockages (fluid, growths) within the middle ear results in what is known as conductive hearing loss, because it is the conduction of sound energy that is disrupted.

Figure 2

Middle Ear Ossicles



Source: Noussios, G., Chouridis, P., Kostretzis, L., and Natsis, K. (2016). Morphological and morphometrical study of the Human Ossicular Chain: A review of the literature and a meta-analysis of experience over 50 years. *Journal of Clinical Medicine Research*, *8*(2), 76–83. https://doi.org/10.14740/jocmr2369w.

Eustachian tube

The eustachian tube is a cartilaginous tube lined with epithelial tissue connecting the middle ear space to the nasopharynx (Bluestone & Doyle, 1988). The primary functions of the ET are equalizing middle ear pressure, preventing nasal secretions from entering the middle ear space, and draining secretions from the middle ear space into the nasopharynx space (M.E. Smith et al., 2016). Bluestone and Doyle (1988) describe eustachian tube dysfunction (ETD) as when there is a disruption in the tubal function, resulting from a patulous (too open) or obstructive (too closed) ET. At rest, the Eustachian tube remains closed and is opened during actions such as yawning, swallowing, or sneezing to equalize the air pressure in the middle ear space and the atmosphere. The muscle associated with opening the eustachian tube is the tensor veli palatini muscle. Bluestone and Doyle suggest that the pterygoid muscle may assist the natural passive forces present when the tube is closing (Bluestone & Doyle, 1988).

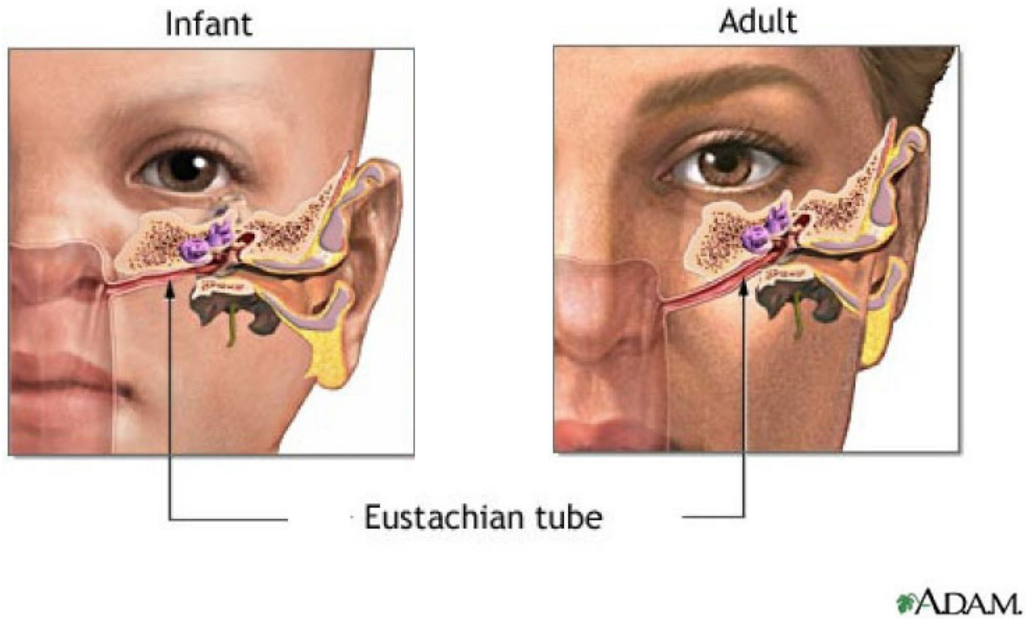
Eustachian Tube Dysfunction

To further understand the developmental anatomy of the ET, 78 tomography scans were randomly selected from a collection of Dartmouth College resources that were categorized into four age groups defined as less than 4 years, 5-to-7 years, 8-to-18 years, and greater than18 years equating to a total of 156 individual ET assessments (Magro et al., 2021). The average length of the ET was measured to be 32mm within the under 4-year-old group, 37 mm in 5-to-7-year-olds, 41 mm in the 8-to-18-year-old group, and 43 mm for those above 18 years of age. This study ultimately demonstrated that 63% of the ET growth occurs by the age of 5.6 years and 86% of the growth by the age of 11.2 years. The ET angle was also investigated, and investigators reported that the horizontal angle in degrees was 17° for children less than 4 years of age, 21° for 5-to-7-year-olds, and 24° in 8-to-18-year-olds, demonstrating that 63% of the maturation of the horizontal angle occurs by 7.13 years of age, 86% by 14.25 years, and nears full maturation of 95% by the age of 21.38.

Danishyar and Ashurst (2023) explore the idea of a more horizontal canal orientation and anatomical markers that allow the ET to become more prone to inflammation during any deviation from homeostasis of the middle ear environment. A shorter ET length and decreased maturation of the angle of ET orientation in children will allow nasal secretions easier access to the middle ear space and a decrease in the ease at which secretions are drained into the nasopharyngeal space from the middle ear (see Figure 3). Therefore, there is an increased risk of middle ear infections in children compared to adults with estimates of 80% of children experiencing at least one infection during their lifetime with 90% of those occurring before school age (Danishyar & Ashurst, 2023).

Figure 3

Eustachian Tube Angle Difference Child and Adult



Source: A.D.A.M., E., & Kaneshiro, N. (2023). *Eustachian tube: Medlineplus medical encyclopedia image*. U.S. National Library of Medicine MedlinePlus. https://medlineplus.gov/ency/imagepages/19596.htm

Bylander (1980) evaluated the eustachian tube function amongst 53 children (mean age of 7.2 years) and 55 adults using various methods of assessment to determine overall eustachian tube functionality. The assessment included middle ear pressure measures with tympanometry, muscular opening function, pressure opening, pressure closing level, and a determination regarding whether inspiration through the nose resulted in negative middle ear pressure. When comparing the results across exams from the children and adults, Bylander (1980) observed that the pressure at which the opening of the ET closes when equalizing is weaker in children, that children have a wider variety and lower overall middle ear pressures, and the muscle opening strength was weaker for those aged three to six years of age. Muscle opening strength improved after the age of six providing evidence that eustachian tube function can improve with age (Bylander, 1980). Anatomical differences in the ET between children and adults lend themselves to physiologic differences which increase the susceptibility of children to middle ear pathologies such as otitis media, respiratory infections, fluid accumulation, and eustachian tube dysfunction.

Inner ear

The inner ear is located medially to the middle ear and is encased in the temporal bone. Since the inner ear has both boney and membranous portions, the inner ear is often referred to as the labyrinth and can be divided into the cochlea, semicircular canals, and the vestibule (Seikel et al., 2021). The cochlea is the hearing portion of the inner ear.

Oval Window

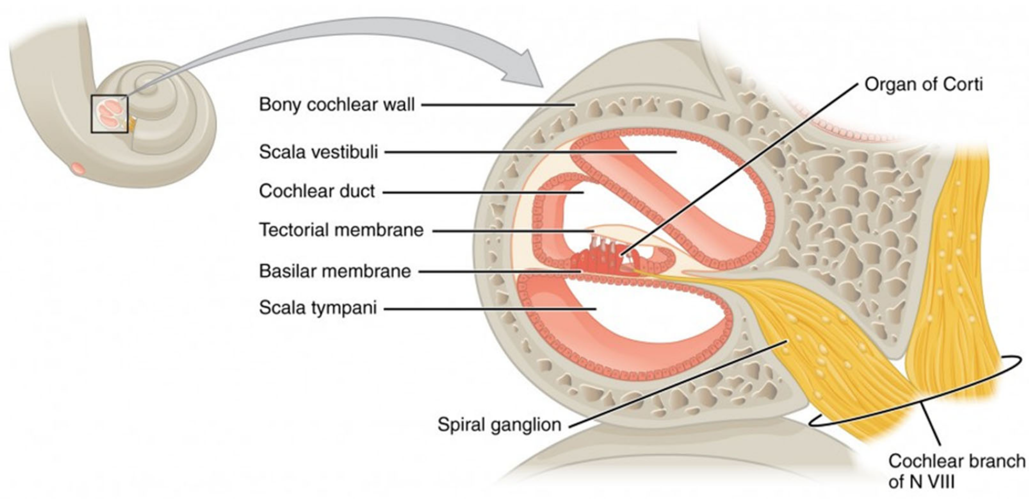
The attachment site for the stapedial footplate functions to transmit sound into the Scala tympani located on the medial wall of the middle ear space. Movement of the stapes footplate against the oval window membrane transmits pressure waves into the inner-ear fluid of the cochlea (Musiek & Baran, 2020a).

Cochlea

The cochlea is the hearing organ with three fluid-filled canals running in parallel defined as the scala tympani, scala vestibule, and scala media (Figure 4). The scala tympani and vestibule are filled with perilymph and the scala media is filled with endolymph. When the oval window is in motion from the stapes causing a pressure wave to flow down the basilar membrane, the length traveled along the basilar membrane will correspond to the frequency of the signal with low frequencies coded at the apex and high frequencies at the basal end (Seikel et al., 2021).

Figure 4

Sectional view of the Cochlea and Organ of Corti



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Scala Media and Organ of Corti

Within the cochlea, a superior boundary of the scala media is termed Reisner's membrane and the inferior boundary is formed by the basilar membrane, this space is defined as the scala media. The scala media is also called the "cochlear duct". The Organ of Corti rests on the basilar membrane and within this area are supporting cells, tectorial membrane, outer and inner hair cells, and their connections to nerve fibers forming the auditory nerve (Seikel et al., 2021). As a pressure wave is presented to the cochlea the basilar membrane moves in response, atop outer and inner hair cells housing the interconnected stereocilia that shear against the tectorial membrane (superior) when the pressure wave displaces the basilar membrane enough resulting in a neural response to the spiral ganglion. The scala media terminates at the round window. As mentioned previously, the basilar membrane and associated cellular matrix codes for specific frequencies in different locations. This is termed “tonotopic organization”.

Stria Vascularis

A highly vascularized system is located within the lateral wall of the cochlear duct and is termed the stria vascularis. It provides blood supply to the inner ear delivering nutrients and oxygen to the system and produces fluid called endolymph located within the Scala media. Ions will be transported into the system as well helping maintain high potassium levels necessary to maintain the endocochlear potential allowing hair cell receptors to function properly (Thulasiram et al., 2022).

Spiral Ganglion

Within the bony modiolus of the cochlea is an intricately connected nerve system of specialized hair cells located within the organ of Corti. When a sensory receptor of a hair cell is triggered by contacting the tectorial membrane an electrical signal will be transmitted through the spiral ganglion along the auditory nerve towards the brainstem (Nayagam et al., 2011). The spiral ganglion is composed of neuron cell bodies of bipolar neurons innervating the hair cells of the Organ of Corti. The tonotopic organization continues to be maintained at this level and throughout the central auditory system.

Central Auditory Nervous System

Perception of sound occurs within the auditory cortex and auditory information must ascend through a pathway to accomplish this described by Peterson (2023). Neural circuitry spans from the auditory nerve up the brainstem to the auditory cortex and back down which carries auditory signals. This intricate pathway passes along several structures and nuclei, each playing a specific role in the interpretation of a signal. The pathway is defined as the cochlear nucleus, superior olivary complex, inferior colliculus, medial geniculate nucleus, and auditory cortex (Peterson, 2023).

This intricate and complex system within the ear can be interrupted at any point in collecting and interpreting the signal is defined as a hearing loss. Understanding these structures allows us to differentiate where an issue is in the system and how a hearing loss might impact individuals.

Hearing Loss

For normal hearing to exist all these structures must function within normal limits otherwise hearing loss occurs. A hearing threshold is defined as the lowest pure-tone intensity to elicit a behavioral response (representing the perception of the sound) and is plotted on a specialized graph called an audiogram Working Group on Manual Pure-Tone Threshold Audiometry, (2005). Pure-tone audiometry (air and bone conduction) is performed to measure the degree of hearing loss. The audiogram plots the intensity of sound in dB hearing level (dB HL) along the y-axis and frequency in Hz along the x-axis (Figure 6). Hearing threshold is defined as the softest intensity a sound is heard 50% of the time Working Group on Manual Pure-Tone Threshold Audiometry, (2005). Hearing loss is present when there exists a pathology within the ear system resulting in an increase in hearing threshold from normative values.

Impaired hearing can also be defined as any disturbance in mechanical sound conduction (transmission of sound) to the inner ear, functionality of the cochlea, auditory nerve, or sound processing of sound in the cortical auditory centers (Zahnert, 2011). According to the World Health Organization (World Health Organization, 2024), a normal hearing threshold exists at 20 dB HL or better for the adult population.

However, this upper limit of normal is typically more conservative for children given the status of their auditory system should be more sensitive during these younger years of development such that thresholds of 15 dB HL or better are considered to represent normal hearing in children (Northern & Downs, 2014). The development of contextual language skills and critical periods should also be considered when assessing the handicapping nature of a hearing loss given patient variability (Lieu et al., 2020).

Prevalence of hearing loss

The prevalence of hearing loss in the US was explored by Tehranchi and Jeyakumar (2020) who assessed data collected by the American Community Survey (ACS) completed from 2011 to 2016. The data set was obtained through the Public Use Microdata Sample which represents approximately 1% of the US population. It was determined that for the sample population, the prevalence rate (per 10,000 individuals) of hearing loss could be approximated to 13.4 for ages zero to two, 0.4 for ages three to seventeen, 3.8 for ages eighteen to forty-four, 18.1 for ages forty-five to sixty-five, and 117.1 for those older than sixty-five (Tehranchi & Jeyakumar, 2020).

Hoffman et al. (2017) completed a cross-sectional analysis of US sociodemographic, health, and audiometric data from 1966 to 2010 was analyzed to understand trends in hearing loss for those aged 12 to 19 years. A large decline in hearing impairment was observed between 1966 to 1970 and then from 1988 to 1994 with no further decline until 2010. From 1966 to 1970 89.4% of youth did not have a hearing impairment within the speech frequencies which grew to 96% in the 1988 to 1994 and 2005 to 2010 surveys. These shifts were partially attributed to a more direct treatment approach for otitis media, more vaccines, less noise exposure., and many other confounding variables. Otitis media was identified to be a significant risk factor for hearing loss but the shift to a more direct medical treatment approach began occurring from 1950 until the 1980s. When utilizing the US National Health and Nutrition Examination Survey from 2011 to 2012 and comparing it to data from 2004 to 2011, the researchers analyzed hearing loss trends for those aged 20 to 69 years old. A total of 3,831, participants provided responses allowing researchers to conclude the prevalence of hearing loss to be 14.2% decreased from 15.9% in previous data sets (Hoffman et al., 2017).

Type of Hearing Loss

The anatomical location of a pathological dysfunction within the auditory system will serve to classify the type of hearing loss an individual experiences. Any pathology that decreases the transduction of sound mechanical energy is considered conductive hearing loss (CHL). Cerumen impactions, tympanic membrane perforations, otitis media, and ossicular chain discontinuities are some of the pathologies commonly associated with CHL (Zahnert, 2011). In terms of cerumen impaction, a patient will likely report a decrease in their hearing sensitivity when the cerumen has partially or completely blocked the acoustical pathway. This creates a temporary CHL since hearing is restored once the canal is cleared (Krouse et al., 2017).

Disturbances to the sensory structures within the cochlea create sensory hearing loss and damage to the neurons in the CANS creates a neural hearing loss. The term sensorineural hearing loss (SNHL) is used when there is damage to both the cochlea and the auditory neural pathway, or when a distinction between sensory and neural cannot be made. Common causes of SNHL can include but are not limited to aging (age-related hearing loss), noise-induced hearing loss, idiopathic sudden hearing loss, vestibular schwannoma, hereditary impairment, and long-standing otitis media (Zahnert, 2011).

Mixed hearing loss (MHL) is defined as a loss that results from conductive and sensorineural dysfunction that occurs simultaneously (J.W. Lee & Bance, 2019). An individual experiencing a sensorineural component within one portion of the ear could also have a conductive component in the outer or middle ear sections with both contributing to the overall hearing impairment.

Central auditory processing disorders (CAPD) occur when there is an abnormal function within the CANS. Specialized tests are used to identify CAPD, as these cannot be distinguished based on pure-tone audiometry.

Severity

Hearing loss can be classified by severity or degree of hearing loss. For adults, the classifications are mild, moderate, severe, and profound. A team of five experts joined to define categories of hearing loss by creating the boundaries of categories summarized below in Table 1 (Margolis & Saly, 2007). Children can also experience minimal hearing impairment when thresholds fall between 15 to 19 dB as previously discussed and included in Table 1 (Northern & Downs, 2014).

Table 1:

Severity of hearing loss is categorized based on pure-tone audiometry for children and adults.

	Minimal (dB HL)	Mild (dB HL)	Moderate (dB HL)	Severe (dB HL)	Profound (dB HL)
Adults	NA	20 to 40	41 to 60	61 to 89	>90
Children	15 to 19	20 to 40	41 to 60	61 to 89	>90

Note: Adapted from: (Northern & Downs, 2014) and (Margolis & Saly, 2007).

Audiometric configuration

As aforementioned, hearing thresholds are visually represented on an audiogram. The configuration or pattern of hearing thresholds plotted on an audiogram is categorized based on the shape of the audiometric pattern (Salmon, 2023). A flat hearing loss occurs when hearing thresholds are similar in hearing level (dB HL) across low, mid, and high-frequency sounds. A high-frequency configuration presents elevated thresholds in high frequencies and normal thresholds in the low- and mid-frequencies. This is also referred to as a sloping loss since the line that connects the thresholds will create a sloped shape as the thresholds get progressively poorer as frequency increases. Low-frequency or reverse-sloping loss exists when low-frequency hearing loss is present with normal or recovering thresholds amongst the highest frequencies. A notched configuration, often seen in cases of noise-induced hearing loss, shows a pattern of maximal hearing loss for 3000 to 6000 Hz with recovery by at least 10 dB in the surrounding frequencies. A U-shaped or “cookie bite “configuration is also commonly used to describe when there is better low and high-frequency hearing compared to mid-frequency hearing.

Laterality

Binaural hearing refers to two ears simultaneously providing the auditory nervous system with auditory information. Advantages of binaural hearing include increased ability to localize sound, improved ability to understand speech in noisy environments, and improved speech and language learning outcomes in children (Friedmann et al., 2016). Monoaural hearing refers to the process of interpreting auditory stimuli from only one ear.

Symmetry

Hearing loss can also be described as symmetric or asymmetric. Asymmetric hearing loss can be described as a 30 dB threshold difference at one frequency, a 15 dB difference at two consecutive frequencies, or a 10 dB difference at three consecutive frequencies (J.W. Lee & Bance, 2019).

Early Identification of Congenital Hearing Loss

For both children (Tomblin et al., 2015) and adults (Doherty & Desjardins, 2015), early identification and intervention for hearing loss has benefits. For children, especially those born with congenital hearing loss need early intervention to ensure speech-language development (Northern & Downs, 2014) and prevent negative impacts on academic achievement (Blair, 1985), psychosocial development (Marnane et al., 2021) and quality of life (Mulrow, 1990).

To ensure timely identification, intervention, and proper follow-up care for children the Joint Committee on Infant Hearing (JCIH: Joint Committee of Infant Hearing., 2019) publishes a best-practice guideline. The guideline includes the implementation of universal newborn hearing screenings (NBHS) in the U.S. The JCIH NBHS (2019) guidelines work to ensure that children are screened by 1 month old, those with hearing loss are identified by 3 months old and receive intervention services by 6 months of age. More recently, for geographical areas consistently achieving this 1-3-6 goal, a newer 1-2-3-month goal setting provides for potentially even better developmental outcomes and is encouraged within the 2019 JCIH position statement. Lieu et al. (2020) state that the first position statement released in 1984 ultimately laid the foundation for a better understanding of pediatric hearing loss allowing researchers to determine that hearing loss will have impacted 1 out of every 5 children and adolescents before the age of eighteen and demonstrated the importance of timely identification and follow-up (Lieu et al., 2020).

Early Identification of Acquired Hearing Loss in Children

Universal newborn hearing screening programs have allowed for early identification and intervention. Earlier diagnosis and access to support and resources result in better developmental outcomes (Pimperton et al., 2017). The Individuals with Disabilities Education Act (IDEA) Part C specifies that children birth to 36 months of age should be provided with adequate early intervention services dependent upon the child’s needs (Yell et al., 2017). Primary care physicians and pediatricians hold the responsibility of monitoring the overall health and well-being of a child including hearing screening, monitoring results, and rescreening (Muse et al., 2013). Consequently, once a child enters the educational system hearing screenings will take place annually. The American Academy of Audiology screening guideline states that a child should at least be monitored in preschool, kindergarten, grades 1, 3, 4, and either 7 or 9 (Bright et al., 2011). Cases of effusion should be monitored more closely as hearing diagnoses will be delayed by associated symptoms (Muse et al., 2013) and concern for ETD exists for younger children (Magro et al., 2021).

Impact of Hearing Loss on Children

Access to sound stimulation is essential for normal speech and language development (Tomblin et al., 2015). Hearing loss in early childhood has a variety of impacts on a child's growth and development including delayed speech and language skills, poor psychosocial skills, and ultimately poor educational and academic performance (Northern & Downs, 2014). The presence of hearing loss in early childhood is known to impact speech production and perception, social conversational skills, literacy, language skills, and overall quality of life/family dynamics (Muse et al., 2013). Hearing loss will not affect any two children the same and an in-depth assessment of hearing status, developmental status, and familial/patient needs is necessary to determine the impacts and potential course for remediation. It is best to understand the impact of hearing loss on speech-language development by first reviewing normal speech-language development for children with normal hearing (Crowe & McLeod, 2014).

Speech and Language Development

During fetal development a fetus will begin receiving acoustic information and fetus responses have been recorded to lower frequency stimuli as early as 19 weeks gestational age and responses to 1000 and 3000 Hz were recorded around 33 to 35 weeks gestationally (Hepper & Shahidullah, 1994). Within the third gestational month, the ear will protrude outwards to further form the pinna and at the time of birth, a newborn has a fully developed outer, middle, and inner ear including a cochlea ready to receive acoustic stimulation. This period is particularly sensitive to inner ear development and maturation (Lavigne-Rebillard et al., 1985).

At the time of birth, a newborn has a fully developed outer, middle, and inner ear including a cochlea ready to receive acoustic stimulation. Neural networks in the brain are predisposed to the acquisition of language especially regions 10, 11, and 34 relative to

Brodmann's regions. These areas are ready to receive and continuously analyze auditory stimulation provided to begin building contextual strategies necessary for organizing and segmenting speech stimuli. Through this process, over time children will learn, explore, and develop speech and language skills important for verbal communication. Lack of adequate access to sounds for a child will likely result in a delay in speech and language skills (Tomblin et al., 2015).

Auditory stimulation provides a foundation for building contextual strategies for organizing and segmenting speech stimuli through continuous exposure. Through this process, over time, children will learn, explore, and develop speech and language skills important for verbal communication. Without access to sound a child will likely struggle with developing speech and language skills (Carney & Moeller, 1998). The first five years of normal development are termed the critical period for language acquisition in which language can most easily be developed. Therefore, if hearing loss occurs during this period, it will increase the likelihood of having an impact on speech and language skills. However, perilingual hearing loss, or hearing loss that occurs within the critical period, and post-lingual hearing losses that occur after but close to this critical period can also pose risks to a child's speech-language development (Northern & Downs, 2014).

Pragmatic language skills, the social use of language, is an area of increased concern for children experiencing hearing loss (Tomblin et al., 2015). Children experiencing hearing loss at younger ages experience a larger deficit in pragmatic language abilities (Rezaei et al., 2021) and may also associated with behavioral or attentional issues (Hall et al., 2018) and lower literacy skills (Blair, 1985) when compared to normal hearing peers.

The rate of identification and amplification regardless of severity can allow for better speech and language outcomes in events of timely and appropriate treatment through providing less restricted language exposure (Muse et al., 2013). Those children being identified and fit with amplification in the population tend to demonstrate the most success (Doherty & Desjardins, 2015). The improved timeliness of identification and intervention gives children access to amplification earlier and in most cases, promotes a within one standard deviation improvement in language ability (Tomblin et al., 2015). Minimizing the impacts of hearing loss on speech-language skills depends upon meeting the early detection guidelines, the severity of loss (less severe hearing losses demonstrated a lesser impact), and increased involvement in a speech-rich as well as adequate exposure to auditory input (Yoshinaga-Itano et al., 2020).

The impact of hearing loss on a child's speech-language development is dependent upon several factors including severity, configuration, stability etiology, and onset of hearing loss. The relationship between the degree of hearing loss and the degree of language impairment has a known association; as the severity of the hearing loss increases the access a child has to auditory input decreases, resulting in a poorer trajectory for speech and language. However, there does not exist a one-to-one relationship between the amount of hearing loss and language delay given the variability seen across children (Yoshinaga-Itano et al., 2020).

Time of Onset of Hearing Loss

The onset of hearing loss in children varies with some occurring congenitally or some that acquire it later in life. In addition, some etiologies may result in fluctuating, progressive, or present later within the developmental periods which creates a more complex environment for growth. Hearing loss in children is often classified with the time of onset and speech and language developmental milestones. A child experiencing the onset of hearing loss between birth to age two is classified as having a prelingual hearing loss, while those with an onset of hearing loss between ages two to four are classified as perilingual, and the onset of hearing loss past age four is classified as post-lingual (Northern & Downs, 2014). The strategies for habilitation and rehabilitation of speech and language differ as a function of onset.

Degree of Hearing Loss

The degree of hearing loss is known to influence speech and language development. In a study by Delage and Tuller (2007), nineteen adolescents aged from 11 to 15 years old located in France were selected to participate, all of whom experienced a hearing loss of mild to moderate degree. The researchers assessed the prevalence of language impairment amongst the participants in comparison to typically developing children. Ten of the nineteen adolescents diagnosed with hearing loss (52.63%) were identified with some degree of weaker language performance of at least 1.65 standard deviations below typically developing children on at least two of the three language tests administered. A strong correlation was observed between hearing loss and phonology, with 63.2% of participants exhibiting impaired phonology skills. Additionally, morpho syntactical abilities were impaired in 31.6% of participants diagnosed with hearing loss. However, receptive language, written language, and vocabulary were relatively comparable to typically developing children within this population (Delage & Tuller, 2007).

Persson et al. (2022) aimed to determine the effect of moderate hearing loss on a child's expressive vocabulary fifteen children previously identified with hearing loss were selected to be assessed at 18 months, 24 months, and 30 months. Inclusion criteria included a four-frequency pure tone average of 30-60 dB HL, receipt of amplification between two and six months of age, without a diagnosed syndrome, and one parent speaking native Swedish participated in a study from the Stockholm region with approximately 2.3 million inhabitants. Eight of the eligible children completed the study and a control group of eight normal-hearing children were recruited from two pediatric care centers in the same region. A reference group from Wordbank was also used which included 420 boys. The second version of the Swedish Early Communicative Development Inventories using words and sentences was used to document expressive language abilities. Early consonant production was examined through the collection and analysis of a standardized 30–45-minute observation of a child in a free-play setting. The number of different true consonants produced at 18 months varied from zero to three in those with hearing loss and from three to nine consonants in normal-hearing children. Word production skills were identified to be similar across all three groups at the 18-month measurement demonstrating similar expressive vocabulary. At 24 months, those with hearing loss demonstrated fewer words with a mean percentile of 30 compared to normal hearing peers at the 55^{th} percentile. This difference persisted with age, at 30 months old the percentile was 53 for children with hearing loss and 78 for those with normal hearing, Greater variability was seen amongst children with hearing loss. The correlation assessment of true consonants and the number of words produced by the children aged from 18 to 24 months was statistically significant, indicating a need to monitor early speech production in children experiencing a moderate degree of hearing loss who have been properly fit with amplification promptly (Persson et al., 2022).

Educational and Psychosocial Impacts of Hearing Loss

Experiencing even minimal or mild hearing loss during childhood is known to have impacts on academic performance and psychosocial development. As mentioned previously, the characteristics of hearing loss and individual characteristics of the child/adolescent will create variable outcomes. However, studies have attempted to control some of these factors.

Bess et al. (1998) sampled 1,208 children to determine the prevalence of minimal sensorineural hearing impairment in children and assess their academic performance. The sample was divided into experimental groups by grade level; grade 3 (n=565), grade 6 (n=350), and grade 9 (n=303). The overall prevalence of minimal hearing impairment was 5.4% and any degree of hearing loss was 11.3% of the sample. Each child was administered a battery of tests selected to identify any connections between hearing loss and altered educational performance or functional status. Third-grade children with minimal hearing loss were found to have significantly lower scores in reading, vocabulary, overall reading achievement, language mechanics, phoneme analysis, spelling, and science when compared to an age-matched group with normal hearing. No differences in academic performance were noted in grade levels 6 and 9. The Picture-and-Word Dartmouth Primary Care Cooperative Information Project Charts (COOP) were used to assess grades 6 and 9 regarding functional status, defined as the ability to perform and adapt to changing environments subjectively and objectively. Scores demonstrated higher dysfunction for children with HL in 9 out of the 10 domains assessed. Those with hearing loss in grade level 6 had significantly higher dysfunction in subtests of self-esteem and energy than students in grade 9 . Minimal hearing loss also led to increased dysfunction in grades 6 and 9 in terms of social support systems, stress, and self-esteem in comparison to peers with normal findings (Bess et al., 1998).

Language plays a significant role in psychosocial development, and therefore delays in language development may have psychosocial impacts in children. Wong et al. (2018) aimed to determine the effects of hearing loss on psychosocial development by the age of five when children (n=317) were fit properly with amplification by the age of three. A review of childhood development inventory (CDI) questionnaires from parents with children experiencing hearing loss revealed a mean score within the normal range. However, there was a large amount of variation in psychosocial and motor development and some children fell below the normative cutoff scores. The Goodman's Strength and Difficulties Questionnaire (SDQ) from a subset of 45 children was also administered. Outcomes on the SDQ revealed a similar pattern with the mean scores within normal limits, yet some children fell more than two standard deviations below normal in the areas of hyperactivity, peer problems, conduct or prosocial behavior, and total difficulties. The difficulties that were observed were primarily attributed to limited verbal communication, decreased production of intelligible speech, and poor language comprehension (Wong et al., 2018).

Wake et al. (2004) examined 5,500 children (7 and 8 years) diagnosed with a hearing impairment ranging in severity from mild to profound. Children were selected from the Health of Young Victorians Study in 1997 designed to research the epidemiology of hearing loss in children. Researchers administered an abbreviated 28-item version of the parent-proxy child health questionnaire focusing on the assessment of role/social, behavior, and mental health. These researchers observed that children with hearing loss scored lower than their age-matched normal hearing peers. A Psychosocial Summary Score obtained from the parents of children with hearing loss, demonstrated poorer scores, with 10-11% of the variance in the data accounted for by slight and mild hearing loss classifications (Wake et al., 2004). Children with hearing loss struggle with social domains within the educational system as they tend to internalize things more frequently and can also suffer from some emotional issues such as decreased well-being and self-esteem or increased rates of anxiety or depression (Lieu et al., 2020).

Educational difficulties were explored by Runnion and Gray (2019) including failing grades, reduced productivity, and behavioral issues that have been associated with hearing loss, even for children with unilateral hearing loss. Acquisition patterns of early literacy skills such as print concepts, alphabet knowledge, phonological awareness, and oral skills are delayed in children with hearing loss. These outcomes strongly correlate with a deficit in sound-to-letter correspondence, which impacts the sequential acquisition pattern of literacy skills. When these skills can't build upon one another, a deficit in reading performance occurs. Print concept knowledge may also be delayed in children with hearing loss which functionally results in further reading difficulties. Without fundamental early literacy skills, a child may later struggle with decoding and ultimately reading comprehension (Runnion & Gray, 2019).

Unilateral Hearing Loss

Children with unilateral hearing loss also experience poorer educational outcomes and hearing loss impacts their overall development and academic performance. Culbertson and Gilbert assessed 50 children divided into two experimental groups; 25 with normal hearing and 25 with a unilateral hearing loss of at least 45 dB HL within the speech frequency range of 250 to 4000 Hz. No significant differences were observed in intelligence quotient (IQ), reading ability, or math performance. Children with hearing loss had increased difficulty with word decoding, written spelling tasks, picture completion (intelligence measure), and block design subscales assessing visual-spatial ability, constructional praxis, motor skills, and problem-solving abilities. Lower ratings for children with hearing loss were also reported from classroom teachers within dependence/independence, attention to a task, emotional lability, and peer relations or social confidence perceived as poorer than the normal hearing peers. These outcomes suggest that children with unliteral hearing loss experience more difficulty in the classroom in terms of behavior and academic performance (Culbertson & Gilbert, 1986).

A 2004 review conducted by Lieu revealed that 22-35% of children experiencing unilateral hearing loss had to repeat at least one grade. Another 12% received additional educational assistance and 41% required resource support. This suggested that children with unilateral hearing loss have classroom behavioral issues, need educational assistance, and have higher rates of grade failures when compared to their normal hearing peers. Intelligent quotient scores in individuals with unilateral hearing loss were significantly lower in children with severe to profound HL compared to those with a mild moderate degree of loss. Children experiencing unilateral hearing loss also demonstrated significantly delayed language in comparison to normal-hearing children. Interestingly, those with right unilateral hearing loss have poorer outcomes within a battery of verbal tests compared to those with left unilateral hearing loss (Lieu, 2004). This may be related to a phenomenon known as the "right ear advantage" where information received from the right ear is at a slight advantage compared to information received from the left ear since the information from the right ear mostly goes directly to the left temporal lobe where speech processing occurs in the brain. A full discussion of the right ear advantage is beyond the scope of this research paper (Sendesen et al., 2023).

Listening effort is defined as the allocation of mental resources needed to overcome obstacles when in the pursuit of a task or goal and is perceived to be increased in children experiencing HL (Hsu et al., 2021). Brännström et al. (2022) theorize that a child with hearing loss must delegate greater cognitive resources to complete a task when listening to a speaker with poor voice quality in the presence of background noise typically present within classrooms. This increases fatigue, ultimately leading to a decreased availability of cognitive resources remaining to allocate elsewhere such as comprehension of subject material (Brännström et al., 2022). Unilateral hearing loss can result in comparable listening fatigue when compared to an individual with bilateral hearing loss and may be best identified by the child, rather than school staff or guardians (Bess et al., 1998).

Etiologies of Childhood Hearing Loss

Etiology refers to the underlying cause of impairment and hearing loss has various etiologies and is often classified into the following categories.

Congenital

Genetic

Congenital losses are typically hereditary, and the most common birth defect identified worldwide (Korver et al., 2017). Hearing losses with a genetically inherited origin present mostly as non-syndromic, having no association or symptoms other than hearing loss. Several genes are associated with hearing, but one commonly known genetic cause for congenital hearing loss is a mutation on the GJB2 gene responsible for encoding connexin 26. This gene is responsible for gap junction function within the cochlea.

Genetic hearing losses that are syndromic occur with children presenting one or more additional signs or symptoms (Bayazit & Yilmaz, 2006). Gettelfinger and Dahl (2018) discuss genetic hearing losses associated with syndromes and the multiple inheritance pathways that exist including autosomal dominant, autosomal recessive, sex-linked, and mitochondrial. Common autosomal dominant syndromes are neurofibromatosis II, Branchio-Oto-Renal, Stickler, Treacher Collins, and Waardenburg Syndrome. Autosomal recessive syndromes are Usher, Pendred, Jervell, and Lange-Nielson Syndrome. Alport and Down's syndrome have also been linked to hearing loss (Gettelfinger & Dahl, 2018). Genetic hearing losses may be conductive, sensorineural, or mixed.

Infectious or Viral

One well-known congenital hearing loss etiology is cytomegalovirus (CMV). A study population of 307 children with some marker for CMV demonstrated a 22.7% incidence rate of fluctuating sensorineural hearing loss and 18.2% of the population experienced delayed onset of hearing loss of least 27 months (Fowler et al., 1997).

Meningitis is inflammation of the tissues surrounding the brain and meninges often attributed to a bacterial infection or a virus (Marcus & Walter, 2022). Acute bacterial meningitis more typically is associated with sensorineural hearing loss (Jensen et al., 2023). Yildirim-Baylan et al., (2014) noted that the pathogenesis of meningitis may contribute to otitis media in infants under the age of two years.

Acquired hearing loss.

Acquired hearing loss in children is due to etiology that is not present upon birth such as trauma, teratogens, noise, infections including otitis media, etc. (Lieu et al., 2020). Otitis media is extremely common in infants and young children. Hearing loss which results from otitis media is conductive and can be temporary or fluctuating ultimately leading to dysfunction in the stimulation of the CANS (Sanfins et al., 2020).

A child experiencing CHL due to otitis media may only exhibit hearing loss at the peak of infection. A SNHL on the other hand will impact a child’s access to sound at a more permanent rate. Whether or not the hearing loss is fluctuating or stable will impact how much of an effect there is on speech and language development. For example, children experiencing a CHL were found to have greater lexical diversity and clause construction in comparison to children experiencing a SNHL or MHL with a significant influence of maternal education level also identified (Arora et al., 2020). The remainder of this literature review will focus on otitis media (OM), as it is the most common cause of pediatric hearing loss (Türe et al., 2023).

Otitis Media

The International Classification of Disease (ICD) 10th edition (2022) describes otitis media as a middle ear disorder characterized by inflammation, swelling, and redness. Otitis media can be an acute or chronic inflammatory process that can also affect the ossicles of the middle ear and the eustachian tube. Otitis media can be associated with other medical conditions such as upper respiratory infection, influenza, allergy, ventilation tubes inserted in the tympanic membrane, and perforations of the tympanic membrane (Centers for Disease Control and Prevention, 2021).

Klein (1994) states the degree and type of infection may vary resulting in a variety of behavioral or observable presentations. Children may generally report pain in general or specific to their ears (otalgia), pain may also present as tugging or pulling on the ears, drainage from the ear which may also present a smell (otorrhea), hearing loss, fevers, irritability, headache, lethargy, anorexia, and in some cases vomiting. Less commonly a patient experiencing OM may also present tinnitus, vertigo, or nystagmus (Klein, 1994). Klein (2000) also assessed the burden of OM which reported upon common reports from parents regarding their child's behavior during an infection including but not limited to relentlessness, sleep disturbances, frequent disobedience, attention deficits, fidgetiness, distractibility, and impaired social interactions (Klein, 2000).

Classifications of Otitis media

Otitis media can be classified into 3 main types; acute OM (AOM), OM with effusion (OME; 'glue ear'), and chronic suppurative OM (CSOM) (Schilder et al., 2016). The associated definitions of otitis media sub-types and terminology have evolved over the years and are summarized in Table 2.

Table 2

Otitis media subtypes

Term/Diagnosis	Acronym	Description
Otitis media	OM	Describes any condition involving inflammation within the middle ear area.
Acute otitis media	AOM	Rapid onset of otitis media.
Recurrent acute otitis media	RAOM	Three or more documented episodes of acute otitis media within a 6 month period OR four or more documented episodes of acute otitis media within the last 12 month period WITH a recent episode in the past 6 months.
Middle ear effusion	MEE	Fluid within the middle ear space.
Otitis media with effusion	OME	Fluid in middle ear space without signs or symptoms of an acute episode.
Chronic otitis media with effusion	COME	Otitis media effusion lasting longer than 3 months from onset (if known) or diagnosis (onset unknown).
Chronic suppurative otitis media	CSOM	Chronic middle ear inflammation and mastoid mucosa with tympanic membrane damage accompanied with frequent discharge.

Note: Adapted from Schilder et al. (2016)

According to Schilder et al. (2016), acute otitis media is characterized by the presence of fluid in the middle ear, together with signs and symptoms of an acute infection. These include acute ear pain, fever, otorrhea, and general illness. Acute otitis media is often diagnosed by pneumatic otoscopy revealing a bulging or inflamed tympanic membrane, fluid levels present behind the tympanic membrane, tympanic membrane perforation, or discharge located within the external auditory canal (Schilder et al., 2016). Acute otitis media can be referred to as uncomplicated infection with no presentation of otorrhea, non-severe with mild otalgia and a body temperature below 39° C (102.2° Fahrenheit), and severe with the presence of a fever equal to or above 39° C (Varrasso, 2009).

Some children have repeat episodes of AOM which is termed "recurrent AOM" (RAOM). Repeated episodes of ear pain, fever, and illness create considerable distress to children and their parents/caregivers (Schilder et al., 2016). The American Academy of Pediatrics (2021) defines RAOM as 3 or more separate well-documented episodes of AOM within a 6-month timespan or at least 4 episodes within 12 months with another infection following within 6 months (Adam, 2021).

Chronic suppurative (pus-forming) otitis media is due to persistent inflammation of the middle ear with an intact TM but no active infection (Cho et al., 2016). It is important to note that a child experiencing chronic episodes of OM may not react the same to each occurrence, especially in instances when a child experiences frequent upper respiratory symptoms. Left untreated, there can be rare, yet severe complications such as acute or chronic mastoiditis, meningitis, and brain abscesses. Perforation of the tympanic membrane can also occur after acute or chronic OM disease process or treatment such as tympanostomy tube placement.

When there is fluid in the middle ear without signs and symptoms of an acute infection, it is termed otitis media with effusion (OME) or middle ear effusion (MEE). It is also referred to as secretory otitis media. Fluid may build up in the middle ear if the ET isn't functioning properly. Effusions have been identified to be composed of water, cell debris, electrolytes, and other various molecular compounds of a thick and sticky consistency (Kubba et al., 2000). With otoscopy (visualizing the tympanic membrane), middle ear effusion can reveal a retracted TM, which limits the view of the prominence of the malleus lateral process. Effusions can persist for 4 to 8 weeks past the initial infection (Isaacson & Griswold, 2020).

The main symptom of OME is conductive hearing loss due to impaired transduction of sound vibrations through the middle ear due to the presence of fluid in the middle ear space (Schilder et al., 2016). Otitis media with effusion has been identified as the leading cause of acquired hearing loss within the pediatric population with 10% to 38% of children being affected by age three (Zahnert, 2011). Monasta et al. (2012) estimate the global prevalence of hearing loss associated with OM is 30 (range 07-95) per 10,000 individuals.

Isaacson and Griswold (2020) identified the factors that differentiate a diagnosis of AOM from OME. These factors were a bulging tympanic membrane, vascular engorgement in the pars tensa region of TM, visualization of the prominence of the malleus lateral process, and conductive hearing loss (Isaacson & Griswold, 2020).

Epidemiology of Otitis Media

Within the pediatric population, OM is the most common illness in which medical advice and guidance is sought out by caregivers with nearly 24.5 million otitis media-related office visits recorded in the U.S. in 1990 (Klein, 1994). More recently in the US prevalence of OM, early-onset OM, and reoccurring OM were explored using data from the Third National Health and Nutrition Examination Survey from phase I from 1988 to 1994 and phase II from 1991 to 1994. Prevalence of OM increased between phases from 66.7% to 69.7%, early-onset cases increased from 41.1% to 45.8%, and reoccurring cases increased from 34.8% to 41.1%. Thus, demonstrating an upward trend in the prevalence of OM amongst the US population (Auinger et al., 2003). Amongst a Danish cohort selected from a community growing in welfare in recent years cumulative incidence of OM was 60.6% with 16.2% having their first episode by 0 to 6 months and consequently 44.3% with an onset between 7 to 18 months, 39.5% between 19 months to 7 years old (Todberg et al., 2014). A systemic review investigated the prevalence of OM in India where ear infections are a major public health concern. Pooled prevalence ranged from 4.5 to 25.78% and it was concluded to be 3.78% for CSOM, 2.68% for OME, and 0.55% for AOM (Bhatia et al., 2023). Danishyar and Ashurst (2023) report that approximately 80% of all children will experience a case of otitis media during their lifetime, and 80-90% of young children will have otitis media with effusion before starting school (Danishyar & Ashurst, 2023).

Implementation of the U.S. universal NBHS guideline has allowed for increased identification of hearing loss. J. L. Chen (2015) investigated the outcomes of cases referred for follow-up after NBHS. Of particular interest were children whose follow-up hearing testing revealed normal audiologic function and the abnormal newborn screening outcome was attributed to effusion (fluid) in the middle ear or ETD. It was reported that children who bilaterally refer on their NBHS are twice as likely to have otitis media than those who refer unilaterally (J. L. Chen, 2015). When 2,253 infants were followed for the first two years of life the mean cumulative proportion of days in the year children experience effusion was 20.4% in the first year and 16.6% in the second year of life (Paradise et al., 1997). Diagnosis of OME occurred at least once by 6 months of age in 47.8%, at 12 months 79.9%, and by 24 months 91.1% of the sample experienced at least one episode of OME (Paradise et al., 1997).

Acute Otitis Media

Acute otitis media is one of the most common pediatric conditions in which most affected children will experience at least one episode by the age of two (Meherali et al., 2021). Recurrent acute otitis media (RAOM) trends (per 1000 persons) were recently assessed in Korea by Kim et al. (2020) and results indicated a decrease in prevalence from 152.7 in 2012 to 137.4 in 2017, with a significant decrease in prevalence noted for those aged 3 to 6 years. The recurrence rate also declined from 34% in 2012 to 28.2% in 2015 with the most noticeable recurrence differences occurring in the birth to 2 years of age group. These results suggest that the introduction of the 2010 version of the guidelines produced by the Korean Otological Society may have contributed to these declining rates since these guidelines focused on children aged 2 to 5 years. The recommendations that children receive a pneumococcal conjugate vaccine (PCV7) and proper antibiotic treatments may have helped prevent and effectively treat occurrences of the disorder. Furthermore, these authors also discussed that young children in Korea were granted access to free national immunizations beginning in 2014 and this may have furthered the decline in the prevalence of RAOM in Korean children (Kim et al., 2020). The Korean Otological Society most recently updated its guidelines in 2012 to reflect a comprehensive review of research obtained from 2004 to 2009 (H. J. Lee et al., 2012).

A prospective cohort study was conducted in Boston, Massachusetts at two pediatric offices to determine the epidemiology of AOM and the duration of MEE within the first seven years of life (Teele et al., 1989). This prospective study consecutively enrolled children shortly after birth and followed them through the age of 7 years. Attrition took place throughout the study period. The data set that was used for analysis included 877 children that were observed for the first year of life, 698 observed until age three, and 498 children were observed for seven years. Throughout the study, children were observed at every wellness visit, those aged four to seven with a history of middle ear disease were observed every four months, and if there was no history of middle ear disease for those aged four to seven, then they were examined once a year. Information was collected regarding socioeconomic status, sibling or parental history of recurrent acute otitis media, sibling or parental history of asthma, hay fever, or eczema, method of feeding (breast or bottle), and smoking. It was determined that the peak incidence of AOM occurred between 6 and 12 months of age with 62% of the children having at least 1 or more episodes of AOM by 1 year of age and 17% having greater than or equal to 3 episodes by this age. By 3 years of age, 83% of the children had at least 1 episode of AOM and 46% had 3 or more episodes. Another smaller peak incidence occurred between ages 4 to 5 years. A multivariate analysis revealed that risk factors for AOM were related to male sex, sibling history of AOM, early occurrence of AOM (within the first 12 months of life), and not being breastfed. Middle ear effusion persisted for weeks to months following AOM. A prolonged duration of MEE was also associated with male sex, sibling history of ear infection, and not being breast-fed (Teele et al., 1989). OME is considered chronic when the effusion has been present in the middle ear for a minimum of 2 months (Alho et al., 1995). On average effusions persisted within the middle ear space for 23 days in cases of OME and AOM in the Teele et al., (1989) study.

Factors Influencing the Risk of Otitis Media

Immune System, Viruses, and Microbiology

The human immune system will gradually mature with age meaning in the earlier years, children are more susceptible to viruses and bacterial infections. In 2008, it was estimated that globally there were approximately 90 million new cases of influenza reported in children younger than five (Nair et al., 2011). Influenza is one of the many causes of upper respiratory infections that can be linked to otitis media episodes.

To further assess the incidence of upper respiratory infections complicated with AOM or OME, a cohort of 294 children aged six months to three years were observed for a year by physicians and their parents to track all occurrences of upper respiratory infections and otitis media (Chonmaitree et al., 2008). The infection was considered affected by OM when the episode occurred within 28 days from the upper respiratory infection's initial onset. A total of 1,295 infections in the upper respiratory system were identified of which 414 (32%) were complicated by AOM and 203 (24%) were complicated by OME. Viruses associated with higher incidence of OM were defined as coronavirus, respiratory syncytial virus, and adenovirus. Chonmaitree et al. (2008) concluded that the prevention of such viruses could result in a decrease in OM cases in children.

The upper respiratory mucosa includes the nasopharynx and ET, congestion in this area can contribute to ETD ultimately allowing increased aspiration of viruses or bacteria into the ME. Ngo et al. (2016) performed a systemic review of microbiology reports to investigate otopathogens commonly associated with OM, and they found that Streptococcus pneumoniae primarily results in cases of AOM and Haemophilus influenzae is predominantly responsible for cases of OME, recurrent AOM, or treatment-resistant AOM. Moraxella catarrhalis was identified most frequently when using PCR analysis and demonstrates some association with cases of AOM, especially in early childhood (Ngo et al., 2016).

Vaccination Status

Pneumococcal conjugate vaccines (PCV) offer protection from OM resulting from viral infections. PCV7 specifically reduced the risk of recurrent OM, bilateral OM, or multiple TM perforations resulting from OM and CSOM around 9 months old for children predisposed to a higher risk of infection (Nascimento-Carvalho, 2009).

Allergies

OM is multifactorial and risk factors include allergic rhinitis inflammation of the nose resulting from the introduction of an antigen especially considering the likelihood of ETD in conjunction with allergic rhinitis due to nasal inflammation. At least 50% of patients identified with OME were involved with allergic rhinitis (Fireman, 1997). Another study identified little to no difference between OME and a control group suggesting the relationship between OME, and allergic rhinitis is not casual while they may occur in conjunction with one another (Yeo et al., 2007).

Breastfeeding

Some parental actions or influences have been identified as risk factors for OM. The benefit of breastfeeding is well understood with linkage to better overall health of the infants and likely extends to help prevent episodes of OM. Significant links between breastfeeding and reduced cases of AOM were observed in a meta-analysis by Bowatte et al. (2015). Twenty-four studies were included in the metanalysis. An effect size estimate and 95% confidence intervals for the association between breastfeeding and the occurrence of AOM were provided for each study. Outcomes provided significant evidence suggesting that strictly breastfeeding within the first 6 months of life accounted for a 43% reduction in occurrence of AOM within the first 2 years of life. There was also evidence that the occurrence of AOM was reduced when there was an increase in the frequency in which children are breastfed, even with some inclusion of formula feeding, within the first two years of life. Abrahams and Labbok concluded in 2011 human milk further provided infants with immunomodulatory agents, anti-inflammatory, and anti-microbial properties to further boost and optimize immune system function compared to formula.

Environment

Working parents often place their children in the care of others at daycare facilities and programs in which they will intermingle with other children this was explored by K. -W. K. Chen et al. (2019). Each child in a facility introduces their unique microflora to the group. Thereby, increasing each child's microbial load resulting in an increased rate of infections and viruses, associating daycare attendance and otitis media (K. -W. K. Chen et al., 2019). Similar effects occur with the presence of siblings in home life, especially those that are older being more likely to introduce a larger array of bacteria into the home, increasing the incidence rate of otitis media during the second year of life (Labout et al., 2011).

Cigarette Smoking

Amani and Yarmohammadi (2015) explored how pediatric exposure to cigarette smoke can alter the surface mucus lining of the respiratory system ultimately affecting the ciliary function within the epithelium located within the respiratory tract, middle ear space, and eustachian tube. When assessing links between parental smoking to AOM, it has been observed that children exposed to tobacco smoke experienced more fevers and hearing loss. The TMs were also noted to be more inflamed in children exposed to cigarette smoke. Asthma, recurrent ear pain, enlarged tonsils, and respiratory problems have all been observed to occur at higher rates in children exposed to tobacco smoke under the age of twelve (Amani & Yarmohammadi, 2015). Parental smoking in the same environment as a child was also significantly linked to episodes of OME with an increased incidence with heavier smoking habits (Tarhun, 2020).

Socioeconomic Status

Parent or family socioeconomic status can correlate to the overall health of a child with lower income associated with poorer health (Rajmil et al., 2014). The socioeconomic level was further explored regarding seasonal effects in Brazil. Castagno and Lavinsky (2002) selected children (n=156) aged 3-4 from both high and low-income households and excluded children from the middle class to limit any potential bias. Otoscopy and tympanometry were conducted in the fall, winter, and spring seasons. Middle ear fluid was more likely to be identified in lower socioeconomic-class subjects when compared to high-socioeconomic subjects. The prevalence and incidence rates of serous otitis media reached their height during the winter months, consisting of colder and wet climate in Brazil, for both socioeconomic levels. The incidence rates were 72.9% across participants in lower socioeconomic classes and reduced to just 18.4% across upper socioeconomic class participants. The poorest prognosis for spontaneous resolution of OM occurred in children identified with having a type B tympanogram in the fall season with at least 96% of cases persisting into the winter and persisted with 73% of those continuing to present fluid symptoms in the spring (Castagno & Lavinsky, 2002). D. F. Smith and Boss (2010) completed a systemic review and found the most identified risk factor for OM is socioeconomic status with deprivation resulting in increased risk of OM. However, within this review, a considerable amount of variability was attributed to ethnic and racial disparities among the samples analyzed (D. F. Smith & Boss, 2010).

Genetics, Race, and Ethnicity

The relationship between OM and ethnicity and genetics has been unclear but researchers have aimed to deepen our understanding of the potential connections. The proportion of African American infants to White infants experiencing OME was found to be higher in a Pittsburg sample (Paradise et al., 1997). Woods (2003) analyzed a sample of 3,108 children with at least one OM-related visit selected in which the racial proportions were defined as 45% African American, 26% Latino, and 29% white. Within these outcomes, however, there were no statistical differences in the number of visits with OM diagnosis, the mean number of episodes per child, or the ratio of office visits compared to OM diagnosis. A two-year follow-up study of 116 participants showed Latino children experienced similar numbers of OM episodes compared to white children with African American children experiencing the fewest OM episodes. There is no clear and consistent correlation between race/ethnicity and the risk of developing OM in childhood (Woods, 2003).

Vernacchio et al. (2004) spearheaded a multivariable model that was used to isolate the statistical interaction between race and the diagnosis rate of OM in infants. African American and Asian infants were observed to be diagnosed with OM less often than Caucasian infants. The authors suggested this was more likely a result of access to healthcare or the rate at which caregivers seek medical attention, rather than racial differences in biological propensity (Vernacchio et al., 2004). For the relationship between OM and genetics, the relationships are much more complex recently it has been identified to potentially have some involvement in the frequency of OM episodes (Kondyarpu et al., 2021).

Eustachian tube function

Bluestone and Doyle (1998) provided a review of the literature regarding ET anatomy and physiology concerning susceptibility to OM. An abnormally patent ET allows for increased free flow of air and nasopharyngeal secretions into the middle ear space resulting in some cases of reflux-related OM infections. Secretions were found to be most likely to enter the middle ear space when the ET opening was in a state of increased compliance. Tubal compliance is ultimately tubal resistance of airflow between the middle ear and nasopharyngeal space to maintain the resting state is compromised therefore allowing a freer flow of air or fluids (Bluestone & Doyle, 1998).

Takasaki et al. (2007) reviewed the angle and length of the ET in 54 child ears with OME to assess the relationship regarding the susceptibility of children to OME. The length and angle of the ET were found to be smaller in children, as expected, in comparison to adults. However, there was no evidence supporting a statistical difference between ET angle and length in children with and without OME. This study demonstrated that the anatomical features of the ET may not contribute to the susceptibility of children to OME or other types of OM in isolation (Takasaki et al., 2007).

Oro-facial anomalies

Cleft lip and palate are congenital oro-facial anomalies resulting from anatomical and structural defects relative to velopharyngeal function and were explored by Kuo et al. (2013). There is a strong association between cleft lip and palate and the occurrence of OME and CHL in those with anatomical differences. An increased risk for infection exists due to the ability of bodily fluid reflux within the system that would result in inflammation of the eustachian orifice or hypertrophy within adenoid pads ultimately leading to eustachian tube obstruction or ETD in which a secondary OME infection will likely be the result. Comorbidity with OME increases medical treatment difficulty (Kuo et al., 2013).

Another review (Sait et al., 2022) aimed to decipher the connections between Trisomy 21, commonly referred to as Down syndrome, and the increased incidence of OME. Children with Trisomy 21 often experience weakened immune systems due to impaired T and B lymphocyte activity, mid-facial flattening and anatomical differences associated with adeno-tonsillar hypertrophy, decreased tensor veli palatini muscle tone, and alterations in cartilage consistency. These conditions lead to a higher risk of reflux and inflammation, as well as ETD, that ultimately contribute to the accumulation of fluid in the middle ear space and an inability to respond appropriately to pressure changes in the middle ear system. Given the reoccurrence or persistence of these infections, these individuals often will need more aggressive medical treatment and intervention (Sait et al., 2022).

Autism

Adams et al. (2016) conducted a retrospective case review conducted from records available from the TRICARE Management Activity Health System identified 48,763 children ranging from 2 to 18 years of age with at least two diagnostic codes for autism and a group of controls consisting of 243,810 children closely age-matched. Children diagnosed with autism are significantly more likely to be diagnosed with AOM, OME, placement of PE tubes, and otorrhea compared to normal-hearing peers. Children with autism had an initial mean age of diagnosis identified as slightly lower with complications such as mastoiditis and cholesteatomas observed more frequently and more likely to require surgical intervention such as a mastoidectomy or tympanoplasty. Observations within the autism-affected population were attributed to impaired communication of symptoms and lack of cooperation during pneumonic otoscopic exams (Adams et al., 2016).

Treatment options

Watchful Waiting

Varrasso (2009) reports the most common treatment for initial cases of OM is a noninvasive observation or "watch and wait" option in which the presence of an infection is placed on a caregiver and physicians' radar, with medical or pharmaceutical treatment options not directly pursued. The "watchful waiting" approach was initially introduced by the American Academy of Pediatrics/Family Physicians clinical practice guidelines as a viable treatment option for children with AOM in 2004. In this practice guideline, the watch and wait period can last up to 3 months and treatment plans should be adjusted depending on individual patient needs. Identifying no additional risk of further complication when using the watch-and-wait approach for non-severe infections with a solid follow-up method in place and no significant change in parental satisfaction was observed in comparison to initial antibiotic treatment (Varrasso, 2009).

Pharmaceutical Treatment

Pharmaceutical management is another common approach to OM treatment amongst the pediatric population explored by Vaz et al., (2014). When antibiotic dispensing rates were assessed for children in New England, the Mountain West, and the Midwest regions of the United States, most pediatric antibiotic prescriptions were related to OM. Most of these OM-related prescriptions occurred in children under the age of six, with significantly higher levels in those aged from 3 to 24 months. Respiratory tract infections reportedly accounted for over 3 quarters of antibiotic prescriptions within the pediatric population (Vaz et al., 2014). A primary rise for concern given these findings has been antibiotic resistance in children suffering from cases of acute otitis media. Finnish researchers (2016) uncovered that the antibiotic resistance rate as well as the microbiology present in AOM in Finland has been slightly changing over time. However, Amoxicillin still proved useful in 72% of cases of AOM supporting the use of this antibiotic as the primary line of treatment in Finland (Sillanpää et al., 2016). Recent evidence has also demonstrated the potential benefit of intranasal steroids and the prescription of S-carboxymethyl cysteine for OM treatment in cases of longer-term treatment (Ikeda et al., 2022).

Tympanostomy Tubes

Infections of a more serious or persistent nature may be treated with tympanostomy tubes (TTs) which were first introduced as a potential invasive treatment option for OME by Armstrong (1954) to resolve effusion, restore hearing abilities, and prevent potential speech and language development delays. Since then, TTs have been implemented in treating prolonged cases of AOM and OME, a systemic review of 63 studies provided high-level evidence that children with AOM and OME treated with TTs experience an improved quality of life for up to 9 months following treatment with no significance in preventing recurring episodes (Hellström et al., 2011). Another review of OME literature demonstrated TTs decreased the incidence of OME for 2 years in comparison to the watchful waiting method, but both methods demonstrated similar language development outcomes (Berkman et al., 2013).

More recent research by Heidemann et al. (2015) has investigated children's quality of life using the Otitis Media-6 questionnaire completed by caregivers at 7-time points from before treatment to 18 months follow-up to investigate possible predictors for clinical success using logistic regression analysis. Although there were no significant differences in survey outcomes for children diagnosed with recurrent AOM and children with recurrent AOM/OME, these two groups had significantly poorer quality of life at baseline compared to children diagnosed with only OME. The children with recurrent AOM scored significantly worse on domains of physical suffering, emotional distress, activity limitations, and caregiver concerns as compared to the group without recurrent AOM. Clinical success factors at the 1-month follow-up were diagnostic subgroup, number of physician visits, and interrupted nights. Clinical success factors at 12-month follow-up were associated with many physician visits, interrupted nights, canceled social activities, and not needing repeated surgery. The authors noted that it is important to distinguish between diagnostic subgroups of children having ventilating tube treatment and the QoL of children with OM improved considerably and significantly after ventilation tube treatment.

Balloon nasal auto-inflation

Another noninvasive technique of nasal auto-inflation using an Otovent patented balloon has more recently been explored to trigger a Valsalva maneuver pressure release in the ME space. Potentially acting as a buffer between the watch-and-wait option and further treatment such as tympanostomy tubes, antibiotics, etc. Williamson et al. (2015) investigated nasal balloon auto-inflation in a sample of 160 children. Pulled from a population of 320 children aged 4-11 years prone to OME, caregivers were encouraged to include inflating the balloon 3 times into their daily routine for 1 month. If symptoms of OME persisted caregivers were encouraged to continue the practice of auto-inflation with a balloon for an additional two months, then they would be reassessed with natural resolution kept in mind given the nature of OM. In comparison to standard care, children who underwent additional treatment with the prescription of auto inflation experienced increased tympanometry resolution demonstrating a return to normal function TM. An increased resolution of 11.7% was recorded at 1 month and 11.3% more resolution at 3 months. The relative risk of reoccurrence of OM episodes was also determined to be significantly lower for those in the auto-inflation groups versus a medical or pharmaceutical treatment approach (Williamson et al., 2015). More recently in 2021, Marshall et al. explored the replacement of Otovent balloons with a more affordable and accessible 'party balloon' assessing mechanics relating to the inflation of Otovent. A pilot study used two alternative spherical "party" balloons and a patented Otovent balloon, after a balloon's 20th inflation there was no difference between the Otovent balloons and the other spherical balloons in triggering the Valsalva maneuver and treatment of OM (Marshall et al., 2021).

Future Treatment: Probiotics

*A r*eview of current literature by Coleman and Cervin (2019) investigated the theoretical base of probiotic use in the treatment and prevention process of OM. Concerns for antibiotic resistance and inefficiency grow annually so other treatment options are being explored. Current literature revealed that local administration and niche-specific probiotic applications demonstrated the ability to prevent and treat OM. Further investigation is required to further assess the efficiency and efficacy of this treatment method in the long term (Coleman & Cervin, 2019).

Impacts of Otitis Media

Impacts on Children

Children predisposed to OM risk criteria may experience middle ear effusion for approximately one month of each of the first two years of life with some reportedly having effusion present for nearly half of infancy (Teele et al., 1989). This can impact a child in many ways throughout the infection. Homøe et al. (2020) reviewed 15 articles to summarize knowledge of OM and its impacts on quality of life. Negative associations were identified with auditory processing skills, language and speech development, school readiness, social competence, psychosocial well-being, mood, and sleep disturbances (Homøe et al., 2020).

To further determine the impacts of OME on the functioning of the auditory system Al-Salim et al. (2021) performed an audiologic test battery two days before TT placement on children aged 10 months and 11 years of age diagnosed with OME. Effusions that fill the middle ear space can be associated with moderate hearing loss and a significant amount of absent otoacoustic emissions (OAEs). In contrast, ears with no effusion active at TT placement were associated with better hearing thresholds and more present OAEs (Al-Salim et al., 2021). Effects of OM and the auditory system have been summarized primarily as fluctuating HL and central auditory processing, more severe cases revealing permanent HL in the event of damage to the eardrum or rupture or any disruption to the middle ear system, infection to adenoids or tonsils, mastoiditis. An audiologic indication of fluctuating HL due to OME being an air and bone conduction gap equal to greater than 25 dB HL identifies a risk for altered auditory input during an integral time for auditory pathway development (Jamal et al., 2022).

Individuals with OME tend to exhibit auditory processing difficulties. For example, they have been shown to perform below average on the gap in the noise test and the dichotic digit test suggesting children with a history of OME may experience an auditory processing disorder (APD) to some degree. Ultimately, supporting the link between fluctuating hearing loss and APD (Khavarghazalani et al., 2016). It is theorized that this relationship is related to delayed maturation of the central auditory pathways due to auditory deprivation experienced during cases of OM. Machado et al. (2020) discovered teenage cases of non-cholesteatomatous COME there were linked to central auditory processing deficits in at least two of the identified areas and unilateral cases were found to have more damage and residual effects than binaural cases (Machado et al., 2020).

Blom et al. (2015) described a more serious complication of OM as the development of cholesteatoma, a collection of skin cells within the ear, in which children often require surgical removal of the cholesteatoma as treatment. It was identified that in cases of surgical intervention in patients with chronic OM and cholesteatomas, commonly associated with hearing loss, the status of the malleus postoperatively can predict hearing outcomes, with near original status will be least likely to continue experiencing a CHL (Blom et al., 2015).

Children with COM may experience some balance-related issues. One hundred and twenty-six children diagnosed with COME and 52 healthy controls were selected and assessed using anamnesis, physical evaluation, posturography, and video-impulse tests to evaluate the relationship between COM and vestibular function. Children with COM demonstrated 58.4% experiencing vestibular symptoms in comparison to 2% amongst the control subjects; abnormal vestibular test findings were more frequent, and posturography testing revealed worsened postural balance control. Video-impulse tests and vestibulocochlear reflexes revealed no observable difference between COM and controls. Results suggest chronic middle ear infections are associated with a higher prevalence of vestibular symptoms and abnormal vestibular findings during the examination and a trend between middle ear inflammations and severity of hearing and balance issues was observed (Monsanto et al., 2020).

Caregiver Perspective: Implications of Otitis Media

The degree and type of OM infections vary, resulting in a variety of behavioral or observable presentations. Klein (1994) summarized that children may report pain that is general or specific to their ears (otalgia), pain may be observed when a child tugs or pulls on their ears.

Drainage from the ear which may also present a smell (otorrhea), hearing loss, fevers, irritability, headache, lethargy, anorexia, and in some cases, vomiting can all be symptoms of OM. Less commonly a patient experiencing OM may also present tinnitus, vertigo, or nystagmus (Klein, 1994). In 2000 Klein discussed that common reports from parents regarding their child's behavior during an infection included but were not limited to relentlessness, sleep disturbances, frequent disobedience, attention deficits, fidgetiness, distractibility, and impaired social interactions (Klein, 2000). Severe complications of OM including mastoiditis, TM perforation, CSOM, and cholesteatomas are not commonly observed in developed areas which is attributed to the greater accessibility of healthcare and treatment options (Blom et al., 2015). Circumstances in which OM goes undetected or receives delayed diagnosis result in the absence of necessary treatment or interventions ultimately, increasing the risk of more severe complications.

Decision-making responsibilities

Stephens et al. (2020) report that caregivers need adequate support throughout the diagnosis and treatment process given the pressure they face having full responsibility for making healthcare decisions and any added family or personal consequences resulting from their child's OM. This should be considered at any time when providing guidance or when counseling them through the next steps and treatment options (Stephens et al., 2020). Four electronic databases were reviewed by Meherali et al. (2021) to identify 21 articles related to parents' knowledge about AOM. They found that parental figures were typically poorly informed of AOM and its sequelae which led to parental feelings of uncertainty in helping their child through this process. Uncertainty and unaddressed concerns overall contributed to parental fear and anxiety throughout the treatment process, suboptimal management, inadequate utilization of healthcare services, negative familial impact, and an increased economic burden (Meherali et al., 2021).

Impact on Quality of Life

Blank et al. (2013) investigated Parents and caregivers of 1,208 children with a mean age of 16 months who were asked to complete the PedsQL Family Impact survey (PQLFI), the Patient Reported Outcomes Measurement Information System (PROMIS), and the OM 6-item severity survey (OM-6). Higher OM-6 results were moderately correlated with worse PQLFI scores. OM-6 scores with increased severity resulted in increased caregiver-reported anxiety, fatigue, decreased satisfaction, and depression. Results also varied from a moderate to strong relationship between OM severity and caregiver-reported scores for anxiety, depression, fatigue, and satisfaction. As OM severity worsens so will the impact on caregivers' quality of life (Blank et al., 2013).

Caregivers tend to be information-seeking by nature and have a general desire for information and understanding of the disease or disorder they are dealing with. Meherali et al. (2021) provided a synthesis of research, parents self-reported poor knowledge of AOM given the lack of information provided by healthcare providers which increases uncertainty, stress, fear, anxiety, poor management of infection, inappropriate healthcare use age, and an overall negative impact on family life on Quality-of-Life assessments (Meherali et al., 2021).

Economic Impacts

Children who experience frequent infections may require multiple visits to pediatricians, audiologists, and/or Ear, Nose, and Throat (ENT) specialists requiring caregivers to accommodate travel and time. Projected costs of AOM due to 14 million cases would be $3.15 billion for children under 5 years of age and COME given 810,000 cases would be 1.08 billion

(Gates, 1996) A more recent analysis of nationwide insurance claims for 7.82 million children located in the United States for the calendar year 2010 to 2011 revealed 6.21 million physician visits related to OM (Marom et al., 2014).

Summary

Individuals of all ages can experience HL and can be classified as conductive, sensorineural, or mixed depending upon the pathology. Identification of HL looks different between adults who more frequently experience progressive or gradual onset and children who are more prone to the adverse effects of HL given critical developmental periods. Children with hearing loss may experience a speech and language delay or deficits in social, psychosocial, educational, behavioral, and increased need for additional educational support. Therefore, screening protocols are in place for newborns and preschool to school-aged children to help identify hearing loss in a timely manner and provide the proper interventions to offset these effects. Otitis media (OM) is one of the most common etiologies of hearing loss known to the pediatric population primarily affecting the middle ear space further classified into the following subtypes: AOM, OME, and COME. The presence of OM can cause negative pressure in the middle ear space resulting in pain and discomfort in children companied with otorrhea, discharge from ear canal, HL, and/or, fever. Increased risk of OM is associated with immature immune systems, bottle feeding, exposure to cigarette smoke, involvement in childcare, seasonal effects of weather, and anatomy and physiology of ET in children. Treatment often begins with a “watch and wait” trial which can later be followed with nasal auto-inflation, antibiotics, and tympanostomy tubes. Caregivers must stay patient and well-informed throughout this process given increased caregiver-reported anxiety, depression, fatigue, and decreased overall life satisfaction correlated to OM severity. Children may require a multidisciplinary team including pediatricians, audiologists, and ENTs lack of information or miscommunication results in increased uncertainty and decreased quality of life amongst caregivers. The role of an audiologist is to assist in the diagnosis, counseling, and management of disorders resulting in impaired hearing. Audiologists may often see children presenting with initial concerns with their pediatrician or do not meet passing criteria at a hearing screening. Audiologists are poised as professionals with a good understanding of OM and its effects on children, and thus, should recognize their role in providing parents/caregivers with support and resources to minimize the negative impacts of OM on the child and the family.

CHAPTER II

APPLICATION TO THE FIELD OF AUDIOLOGY

Clinical guidelines for the treatment of otitis media have been established to standardize diagnosis and care for patients. These care choices and timelines for consideration impact caregivers and children in many ways. This chapter will review the clinical guidelines, audiological assessments, and the broader impact on caregivers and patients.

Otitis Media Guidelines

Clinical practice guidelines are systemically built around a synthesis of previously supported knowledge and current research via published medical literature and systemic reviews focused on the applicable area. Clinical practice guidelines should guide specific diagnostic and treatment modalities toward patient interaction and care. Guidelines focus on specific pathologies or populations published by governing bodies of medical professionals to ensure best practices are applied. Patients with otitis media require a complex team approach, in which primary care physicians, pediatricians, audiologists, SLPs, and otolaryngologists are involved in the identification, diagnosis, and management of treatment processes. Consequently, there is more than one professional guideline for OM, and each will be discussed.

American Academy of Pediatrics (2013):

An initial AOM guideline formed by a subcommittee on the management of AOM was published initially in 2004 by the American Academy of Pediatrics (AAP) in collaboration with the American Academy of Family Physicians (AAFP) to provide guidance when encountering

AOM in patients aged 6 months to 12 years old (Subcommittee on Management of Acute Otitis Media; Diagnosis and Management of Acute Otitis Media, 2004). In a 2009 AAP meeting, it was decided that this guideline would need to be revised to provide primary care physicians with an updated framework for interacting with AOM patients aged 6 months to 12 years old and to align with the most recent findings in the research literature. The revised recommendations were published by the American Academy of Pediatrics (AAP) in 2013 a summary of the statement can be found below in Table 3 (Lieberthal et al., 2013).

Table 3

Summary of American Academy of Pediatrics 2013 for Acute Otitis Media

DIAGNOSIS	MANAGEMENT	PREVENTION
1A: Clinicians should diagnose acute otitis media in children who present with moderate to severe bulging of the tympanic membrane or new onset of otorrhea (not in relation to otitis externa).	2: Management of acute otitis media should include an assessment of pain. If pain is present, the clinician should recommend treatment to reduce pain.	6A: Clinicians should recommend pneumococcal conjugate vaccine to all children according to the schedule of the Advisory Committee on Immunization Practices of the Centers for Disease Control and Prevention, American Academy of Pediatrics, and American Academy of Family Physicians. The Centers for Disease Control and Prevention provide further information on the pneumococcal conjugate vaccine; https://www.cdc.gov/vaccines/hcp/vis/vis-statements/pcv.html
1B: Clinicians should diagnose acute otitis media within cases of mild bulging of tympanic membrane and recent (<48 hours) pain onset (holding, tugging, rubbing of the ear in a nonverbal child) OR intense erythema visible within otoscopy.	3A: Severe acute otitis media: Clinician should prescribe antibiotic therapy for acute otitis media (bi- or uni-lateral) for 6 months and older with severe signs or symptoms (ie, moderate or severe otalgia or otalgia for at least 48 hours or temperature 39°C [102.2°F] or higher).	6B: Clinicians should recommend annual influenza vaccine to all children according to the schedule of the Advisory Committee on Immunization Practices, American Academy of Pediatrics, and American Academy of Family Physicians. The Centers for Disease Control and Prevention provide further information on the influenza vaccine:https://www.cdc.gov/flu/professionals/vaccination/vax-summary.htm#children

Table 3 continued

DIAGNOSIS	MANAGEMENT	PREVENTION
1C: Clinicians should not diagnose acute otitis media in children who do not have middle ear effusion (based on pneumatic otoscopy and/or tympanometry).	3B: Nonsevere bilateral acute otitis media in younger children: Clinician should prescribe antibiotic therapy for bilateral acute otitis media in children 6 months to 23 months without severe signs or symptoms (ie, mild otalgia for less than 48 hours and temperature less than 39°C [102.2°F]).	6C: Clinicians should encourage exclusive breastfeeding for at least 6 months.
	3C: Non-severe unilateral acute otitis media in younger children: Clinician should prescribe antibiotic therapy OR offer observation with CLOSE follow-up based on joint decision making with the parent(s)/caregiver for unilateral acute otitis media in children 6 months to 23 months of age without severe signs or symptoms (ie, mild otalgia for less than 48 hours and temperature less than 39°C [102.2°F]). With observation, a mechanism must be in place to ensure follow-up and allows for antibiotic therapy if the child worsens or fails to improve within 48 to 72 hours of onset of symptoms.	6D: Clinicians should encourage avoidance of tobacco smoke exposure.

Table 3 continued

DIAGNOSIS	MANAGEMENT	PREVENTION
	3D: Nonsevere acute otitis media in older children: Clinician may prescribe antibiotic therapy OR offer observation with close follow-up based on joint decision-making with the parent(s)/caregiver for acute otitis media (bi- or uni-lateral) in children 24 months or older without severe signs or symptoms (ie, mild otalgia for less than 48 hours and temperature less than 39°C [102.2°F]). With observation, ensure follow-up and begin antibiotic therapy if the child worsens or fails to improve within 48 to 72 hours of onset of symptoms.	
	4A: Clinicians should prescribe amoxicillin for acute otitis media to treat with antibiotics has been made and the child should not receive amoxicillin if they have in the past 30 days, the child does not have concurrent purulent conjunctivitis, or not allergic to penicillin.	
	4B: Clinicians should prescribe an antibiotic with additional β-lactamase coverage for acute otitis media to if antibiotics are in use, and the child has received amoxicillin in the last 30 days or has concurrent purulent conjunctivitis or has a history of recurrent acute otitis media unresponsive to amoxicillin.	

Table 3 continued

DIAGNOSIS	MANAGEMENT	PREVENTION
.	4C: Clinicians should reassess the patient if the caregiver reports that the child's symptoms have worsened or failed to respond to the initial antibiotic treatment within 48 to 72 hours and determine if a change in therapy approach is needed.	
	5A: Clinicians should not prescribe prophylactic antibiotics to reduce the frequency of episodes of acute otitis media in children with recurrent acute otitis media.	
	5B: Clinicians may offer tympanostomy tubes for recurrent acute otitis media defined as 3 episodes in a 6-month period or 4 episodes in 1 year period with 1 episode in the preceding 6 months.	

Note: Adapted from Lieberthal et al. (2013)

American Speech-Language Hearing Association

The American Speech-Language-Hearing Association (ASHA) in 2020 released an ear infection (otitis media) information series targeted towards audiologists. Clarifying AOM as a bacterial-based infection within the middle ear space sometimes results in middle ear fluid or a build-up of non-bacterial middle ear fluid that results from negative pressure within the middle ear space. The document defines the signs of an ear infection in a child as tugging on an ear, increased crying, cold symptoms, runny nose, fever, restlessness, drainage from the ear, and not responsive to sound. Treatment and diagnosis by an otolaryngologist or pediatrician are recommended. Treatment options consist of "watchful waiting", antibiotic prescription, and TTs in the event of COME. The ASHA notes that a physician should be consulted for medical treatment, and many children require immediate attention. Children with symptoms of OM may also need to see an audiologist for testing of the middle ear status and hearing. Speech-language pathologists can evaluate the child with OM for speech and or language delays.

American Academy of Audiology

The American Academy of Audiology originally published a clinical practice guideline entitled "Audiologic Guidelines for the Diagnosis and Treatment of Otitis Media in Children" in 1992. The 1992 otitis media guideline has since been retired and the AAA now endorses the "Clinical Practice Guideline: Tympanostomy Tubes in Children (Update)" published in 2022 by the American Academy of Otolaryngology-Head and Neck Surgery (Rosenfeld et al., 2022).

American Academy of Otolaryngology-Head and Neck Surgery

The AAA-HNS has two guidelines relevant to otitis media; "Clinical Practice Guideline: Otitis Media with Effusion (Update) (2016) and "Clinical Practice Guideline: Tympanostomy Tubes in Children (Update)" (2022).

Clinical Practice Guideline: Otitis Media with Effusion.

The purpose of this multidisciplinary guideline is to guide the management of otitis media with effusion (OME) and to create clear and actionable recommendations to integrate into clinical practice. Table 4 provides a summary of the key recommendations. It is noteworthy that the guideline has specific recommendations relevant to audiologists performing hearing screening and tympanometry. Patient handouts are also available from AA0-HNS at https://www.entnet.org/quality-practice/quality-products/clinical-practice-guidelines/ome/. The American Academy of Family Physicians endorses this guideline.

Table 4

Summary of AAA-HNS Otitis Media with Effusion Guideline Key Action Statements

Statement	Action
1a. Pneumatic otoscopy	The clinician should document the presence of middle ear effusion with pneumatic otoscopy when diagnosing otitis media effusion in a child if possible.
1b. Pneumatic otoscopy	The clinician should perform pneumatic otoscopy to assess for otitis media effusion in a child with otalgia, hearing loss, or both.
2. Tympanometry	Clinicians should obtain tympanometry in children with suspected otitis media effusion for whom the diagnosis is uncertain after performing (or attempting) pneumatic otoscopy.
3. Failed newborn hearing screen	Clinicians should clearly document in the medical record counseling of parents of infants with otitis media effusion who fail a newborn hearing screen regarding the importance of follow-up to ensure that hearing is normal when otitis media effusion resolves and to exclude an underlying sensorineural hearing loss.
4a. Identifying at-risk children	Clinicians should determine if a child with otitis media effusion is at increased risk for speech, language, or learning problems from middle ear effusion due to of baseline sensory, physical, cognitive, or behavioral factors.
4b. Evaluating at-risk children	Clinicians should evaluate at-risk children for otitis media effusion at the time of diagnosis of an at-risk condition and at 12 to 18 months of age (if diagnosed as being at risk prior to this encounter).

Table 4 Continued

Statement	Action
5. Screening healthy children	Clinicians should not routinely screen children for otitis media effusion who are not at risk and do not have symptoms that may be attributable to otitis media effusion, such as hearing difficulties, balance (vestibular) problems, poor school performance, behavioral problems, or ear discomfort.
6. Patient education	Clinicians should educate families of children with otitis media effusion regarding the natural history of otitis media effusion, need for follow-up, and the possible sequelae.
7. Watchful waiting	Clinicians should manage the child with otitis media effusion who is not at risk with watchful waiting for 3 months from the date of effusion onset (if known) or 3 months from the date of diagnosis (if onset is unknown).
8a. Steroids	Clinicians should recommend against using intranasal steroids or systemic steroids for treating otitis media effusion.
8b. Antibiotics	Clinicians should recommend against using systemic antibiotics for treating otitis media effusion.

Table 4 Continued

Statement	Action
8c. Antihistamines or decongestants	Clinicians should recommend against the use of antihistamines, decongestants, or both for treatment of otitis media effusion.
9. Hearing test	Clinicians should obtain an age-appropriate hearing test if otitis media effusion persists for ≥3 months OR for otitis media effusion of any duration in an at-risk child.
10. Speech and language	Clinicians should counsel families of children with bilateral otitis media effusion and documented hearing loss about the potential impact on speech and language development.
11. Surveillance of chronic OME	Clinicians should reevaluate children with chronic otitis media effusion, at 3- to 6-month intervals, until the effusion is no longer present, significant hearing loss is identified, or structural abnormalities of the eardrum or middle ear are suspected.
12a. Surgery for children <4 y old	Clinicians should recommend tympanostomy tubes when surgery is performed for otitis media effusion in a child less than 4 years old. An adenoidectomy should not be performed unless a distinct indication (ie, nasal obstruction, chronic adenoiditis) exists other than otitis media effusion.

Table 4 Continued

Statement	Action
12b. Surgery for children ≥4 y old	Clinicians should recommend tympanostomy tubes, adenoidectomy, or both when surgery is performed for otitis media effusion in a *child 4 years old or older.*
13. Outcome assessment	When managing a child with otitis media effusion, clinicians should clearly document in the medical record resolution of otitis media effusion, improved hearing, or improved quality of life.

Note: Adapted from Rosenfeld et al. (2016)

It is noteworthy that the guideline has specific recommendations relevant to audiologists performing hearing screening and tympanometry. Patient handouts are also available from AA0-HNS at https://www.entnet.org/quality-practice/quality-products/clinical-practice-guidelines/ome/. The American Academy of Family Physicians endorses this guideline.

Clinical Practice Guideline: Tympanostomy Tubes in Children.

The AAA-HNS "Clinical Practice Guideline: Tympanostomy Tubes in Children (Update)" (2022) has also been endorsed by the International Society for Otitis Media, Society for Pediatric Anesthesia, and Society of Otolaryngology Head-Neck Nurses. The ASHA "supports" the guideline. The AAO-HNS states that the purpose of the 2022 clinical practice guideline is to reassess and update recommendations from the prior 2013 guideline and to provide clinicians with 'trustworthy, evidence-based recommendations on patient selection and surgical indications for managing tympanostomy tubes in children." The guideline is freely available at https://aao-hnsfjournals.onlinelibrary.wiley.com/doi/10.1177/01945998211065662. A plain-language summary is also available at https://aao-hnsfjournals.onlinelibrary.wiley.com/doi/full/10.1177/01945998211065663. The American Academy of Otolaryngology-Head and Neck Surgery Foundation's "Clinical Practice Guideline" third edition coined a quality-driven approach to translating recent evidence into action (Rosenfeld et al., 2016).

Short duration or newly diagnosed OME should be monitored with the date of onset tracked if possible or the date of diagnosis documented as clinicians should no longer perform tympanostomy tube insertion procedures in children with a singular documented episode of OME unless the effusion persists for at least 3 months and results in hearing difficulty (Rosenfeld et al., 2022). This is intended to avoid unnecessary surgical risks and costs associated with tympanostomy tube use given the nature of OME to resolve spontaneously. Children should receive a baseline hearing evaluation before surgery is performed to provide baseline information. The guideline states that children with RAOM at the time of surgery may only proceed with TT if they have uni- or bi-lateral effusion or are considered at increased risk for speech, language, or learning problems related to OM. Long-term tubes are no longer recommended during initial surgery unless there is an anticipated risk for prolonged middle ear issues beyond the scope of a short-term tube option. Physicians are no longer encouraged to routinely prescribe postoperative antibiotic ear drops suggesting a single dose of antibiotics to be delivered in the operating room is sufficient. Post-operation antibiotics to be given by caregivers should only be prescribed in complicated acute TT otorrhea. An adenoidectomy may be performed as an adjunct surgery with tympanoplasty for children with adenoid centralized problems defined as adenoid infection or nasal obstruction or if a child is younger than 4 years of age to reduce recurrent episodes or repeat tube insertion procedures. Throughout this whole process, parents should be educated on the expected duration as well as the general function of the tube and routine water precautions should not be encouraged. Parents should be well informed of the follow-up process necessary until the tubes extrude and detection of complications is also imperative in this process as proceeding with surgery is in large made by the shared decision of a team of physicians and the caregiver (Rosenfeld et al., 2022). The summary of guideline key action statements is provided in Table 5.

Table 5

Summary of AAA-HNS Clinical Practice Guideline: Tympanostomy Tubes in Children Key Action Statements applicable to children 6 months to 12 years.

Statement	Summary
1. Otitis media effusion of short duration	Clinicians should not perform tympanostomy tube insertion with a single episode of otitis media effusion of less than 3 months' duration, from the date of onset (if known) or from the date of diagnosis (if onset is unknown).
2. Hearing evaluation	Clinicians should obtain a hearing evaluation if otitis media effusion persists for 3 months or longer OR prior to surgery when a child becomes a candidate for tympanostomy tube insertion. (Thresholds at or better than 15 dB HL considered normal)
3. Chronic bilateral otitis media effusion with hearing loss	Clinicians should consider bilateral tympanostomy tube insertion to children experiencing bilateral cases of otitis media effusion for a duration of 3 months or longer AND experience hearing difficulty.
4. chronic otitis media effusion with symptoms	Clinicians may perform tympanostomy tube insertion on children with Uni- or Bi-lateral otitis media effusion persisting for 3 months or longer AND exhibits symptoms that may include, but are not limited to, vestibular issues, poor school performance, behavioral issues, ear discomfort, or overall reduced quality of life.
5. Surveillance of chronic otitis media effusion	Clinicians should reevaluate patients at 3- to 6-months intervals and children who do not receive tympanostomy tubes with middle ear effusion. They should be monitored until no effusion is present, significant hearing loss is detected, or structural abnormalities of the middle ear are suspected.

Table 5 Continued

Statement	Summary
6. recurrent acute otitis media without middle ear effusion	If middle ear effusion is not present in either ear with recurrent acute otitis media, then tympanostomy tubes should not be placed.
7. recurrent acute otitis media with middle ear effusion	If middle ear effusion is present in either ear with recurrent acute otitis media, then tympanostomy tubes may be placed bilaterally.
9. TT in at-risk children	Clinicians may place tympanostomy tubes in at-risk children with uni- or bi-lateral otitis media effusion likely to persist with a Type B tympanogram or at least 3 months of documented effusion.
10. Long term tube	Long term tubes should not be placed as an initial intervention method unless there is documented evidence to suggest a prolonged need for ventilation beyond a short-term tube.
11. Adjuvant adenoidectomy	Clinicians may perform an adenoidectomy in conjunction with tympanostomy tube insertion for children with symptoms directly related to adenoids (ie. Infection or nasal obstruction) OR children older than 4 years of age to reduce future incidence of ROM or repeat tympanostomy tube insertion.
12. Perioperative education	Clinicians should adequately educate caregivers of tympanostomy tube expectations, duration of tubal function, suggested follow-up procedures, and signs of complications.

Table 5 Continued

Statement	Summary
13. Perioperative ear drops	Clinicians are advised to avoid routinely prescribe perioperative antibiotic after tympanostomy tube insertion.
14. Acute TT otorrhea	Topical antibiotic drops may only be prescribed in the event of uncomplicated tympanostomy tube otorrhea.
15. Water precautions	Clinicians should not encourage routine avoidance of water exposure with uncomplicated TTs.
16. Follow-up	Surgeon or designated provider should examine the ears within 3 months of tympanostomy tube insertion date AND should educate families the need for and importance of follow-up until the tympanostomy tube extrude from the ear.

Note: Adapted from (Rosenfeld et al., 2022)

Assessment Tools for Otitis Media

The American Speech-Language-Hearing Association (ASHA) most recently defined the scope of practice of an audiologist in 2004. It defines an audiologist as a trained professional who provides patient-centered care in the prevention, identification, and rehabilitation process in areas of hearing and balance. Hearing services include peripheral and central functional components of the collection, transmission, and analytic processing of auditory stimulation. Audiologists often play a large role in the assessment process of disorders affecting the ear anatomically and physiologically. Regarding the pediatric population audiologists are involved in early hearing detection and intervention (EHDI) protocols in applying JCIH protocols for screening procedures, performing diagnostic services, treatment, and providing family support or counseling services. In addition to the aforementioned services, educational audiologists also work to assist in the formation of individualized education plans, individual family service plans, and 504 plans (Ad Hoc Committee on Scope of Practice in Audiology, 2004). Otitis media, as previously discussed, can result in hearing loss making the assessment and monitoring of a child experiencing an episode imperative for proper treatment and resolution. An audiologist’s ability to assess the auditory system of the pediatric population can provide accurate differential information regarding hearing sensitivity ultimately assisting in the proper and timely diagnosis and process of care of OM and its subtypes, especially in the presence of a hearing loss. When audiologists assess children with OM using a battery of diagnostic tests and information is shared, children can be better managed by a multi-disciplinary team approach. Several of these relevant assessments are discussed below.

Otoscopy

Otoscopy is a clinical procedure utilized to visualize the TM requiring an adequate light source and means of magnification. In the pediatric population, the external auditory canal may be narrower than that of an adult, and children are often more restless than adult patients creating some increased difficulty for this procedure (Metcalfe et al., 2021). Pneumatic otoscopy is a visual examination that permits the determination of the mobility of a patient's TM in response to pressure changes applied by the examiner squeezing a bulb attached to the otoscopy (Jones & Kaleida, 2003). Metcalfe et al. (2021) assessed video otoscopy, which allows medical providers and audiologists the ability to capture images of TMs and even remotely complete this process. Advancements in smartphone technology have allowed for video otoscopy by attaching a camera modifier to a smartphone thus creating a more portable option. Smartphone devices are most useful in the presence of a trained physician or audiologist but are commonly utilized at home by caregivers. Otoscopy can provide useful diagnostic information when it comes to patients who present with OM. Otoscopy may reveal an inflamed, irritated with increased vasculature, yellow or brown fluid present behind an intact TM, and bulging or retraction of the TM (Metcalfe et al., 2021).

Rebol (2022) explains OME's association with a collection of fluid within the middle ear space, and when TM visualization takes place during otoscopy, the fluid is most evident in the posterior inferior quarter of the TM. Different types of effusion can be present. A serous effusion reveals a TM with yellow or brown fluid that is thinner in consistency, often allowing for air bubbles to be visualized. A purulent effusion is often compared to pus and is more secretory which may be less translucent than a serous effusion with observable bulging more commonly associated. Mucoid effusions are thick and viscous often causing the TM to appear more greywhite and dull in color with visible signs of retraction. Mucoid effusions are commonly referred to as “glue ear” resulting in thick viscous fluid and negative pressure in the middle ear space resulting in TM retraction. Thus, it is believed that the appearance of the TM holds a large differential diagnostic value with AOM where bulging is often observed and OME when retraction or a neutral position is more common (Rebol, 2022).

Pneumatic otoscopy is conducted via injected pressure into the canal and simultaneously visualizing the movement of the TM in result reducing the subjectiveness observed with traditional otoscopy. This allows for pneumatic otoscopy to be more sensitive to characteristics of OM including effusion (Jones & Kaleida, 2003). A systemic review of 52 studies found that pneumatic otoscopy had the best sensitivity and specificity in suggesting COME compared to other measures within the audiologist’s test battery (Takata et al., 2003).

Otoscopy is also useful in the ‘watchful waiting’ period as well as follow-up applications within the medical treatment route of OM. Newly identified cases of OM will require at least 3 months of observation to see if the condition resolves as well as to track the progress of an effusion or the onset of one. Otoscopy can provide useful information during this period and video-otoscopy can even allow for longitudinal photographic documentation to take place. Following the waiting period medical management can begin in which a physician can pursue medication or surgical treatment, via TTs. The audiologist can assist in the follow-up care of TTs regarding monitoring the healing process, assist in determining if the tubes are non-obstructed or closed, and track the natural extrusion progress of temporary models. It is also possible to observe scarring on the TM evidence of TTs in the past appearing as bright or chalky white calcium deposits on the TM termed myringosclerosis (Musiek & Baran, 2020a).

Speech-Language Screening

An audiologist also receives training in speech-language development and screening techniques, allowing them to be able to conduct an informal speech-language screening during the appointment. This can take place through patient observations, administration of screening protocols, and interactions with caregivers. Case history forms can include questions regarding language development as hearing loss in children is commonly associated with language delays.

Pure-tone Audiometry

Pure-tone audiometry is typically conducted across a frequency range represented on an audiogram plots threshold values, lowest intensity to elicit a behavioral response representative of sound perception, with intensity dB HL along the y-axis and frequency in hertz (Hz) along the x-axis. Sound waves can be conducted to the auditory system via two routes known as air and bone conduction. Air conduction relies on stimulus passing through the outer, middle, and inner ear in which a disruption is indicative of a HL. Bone-conducted sound is presented to the mastoid region of the temporal bone or forehead and conducted directly to the inner ear through the bony structures of the skull. Dysfunction in the bone conduction pathway is considered a SNHL due to dysfunction in the cochlea or cochlear nerve. Stimulation via both routes provides information regarding the type of hearing loss present if any (Zahnert, 2011). An air-bone gap occurs when the air and bone thresholds do not align with one another suggestive of a conductive cause to the HL and in cases of elevated air conduction thresholds with corresponding bone conduction thresholds is suggestive of a SNHL.

Immittance Measurements

Immittance measurements assess the relationship of resistance and reactance to assess the amount of energy transmitted through the system when presenting a stimulus to a sealed ear canal. It is important to note the reactance factor is frequency-dependent with known influences of mass on high frequencies and stiffness on low frequencies affecting the diagnostic approach for younger children known to have a more mass-dominated system. Immittance measures play an important diagnostic role in the process of determining whether the nature of the HL is conductive or sensorineural. Commonly used immittance measurements with pediatric patients are tympanometry, acoustic reflex thresholds, and wideband acoustic immittance.

Tympanometry

Tympanometry is an immittance assessment used to determine the function of the middle ear system and the data obtained is plotted on a graph referred to as a tympanogram (Hamid & Brookler, 2007). They also elaborate on how the plots are analyzed by shape, and specific data points for the peak acoustic admittance (mm H_2o/ML), peak pressure (daPa), and equivalent external ear canal volume (ml or cc) are recorded. The equipment is comprised of a probe containing an air pump, probe speaker, and microphone. To measure a response, a hermetic seal at the ear canal opening is required. The air pump varies the pressure in the ear canal, typically from +200 daPa to – 400 daPa, while a pure-tone probe is simultaneously emitted where the microphone records the signal of what is reflected off the TM. The movement of the TM will result from the admittance value increasing. As the pressure is varied within the ear canal the TM will stiffen causing a reduction of sound conduction through the system resulting in a decreased reactance value. Peak pressure is then measured at the pressure point in which maximum transmission of sound with the pressurized canal for healthy ears commonly occurs at or near 0 daPa which is atmospheric pressure. Middle ear compliance is measured at the height of the peak and discloses the oscillation ability of the TM. Tympanometry is routinely measured using a 226 Hz probe tone for the stiffness-dominated system present in adult ears (Hamid & Brookler, 2007). However, most infant ears are a mass-dominated system, requiring a high-frequency probe tone such as 1000 Hz instead. Hoffmann et al. (2013) evaluated 915 ears from patients under 1 year of age using 226 Hz, 678 Hz, and a 1000 Hz probe stimulus which revealed that high-frequency tympanometry was most appropriate for infants under 9 months of age attributed to the increase of mass within the system during these periods. Tympanograms obtained at 1000 Hz can either be classified as peaked suggesting normal TM function or flat indicating an abnormality in the middle ear system (Hoffmann et al., 2013).

Tympanograms (are interpreted through a class system pioneered by Jerger (1970) who conducted tympanometry (226 Hz) on 142 normal ears, 234 ears with SNHL, and 114 ears with CHL. Participants ranged in age from 2 to 89 years old experiencing varying etiologies of HL. The shape of these pressure-compliance graphs can be classified into 3 main types; A, B, and C. Type A is characterized by a peak at or near 0 daPa (atmospheric pressure) and is primarily associated with healthy ears. A tympanogram that demonstrates a reduced or absent peak is a type B commonly occurring with CHL, frequently referred to as “flat” in morphology. The type C classification refers to a normal-sized peak with a shift to the left due to negative pressure within the middle ear cavity. While slight negative pressure is a common occurrence for normal ears, pressure values greater than or equal to -100 daPa are considered significant negative pressure (Jerger, 1970).

Anwar (1969) demonstrated that tympanometry is effective at diagnosing a CHL resulting from fluid in the middle ear space secondary to OM. An assessment of 63 patients ranged 3 to 12 years of age undergoing a myringotomy procedure revealed the ratio of Jerger type A, B, and C tympanograms and the presence of fluid. Type B and C tympanograms were identified in the right ear 74.6% and 20.6% of the sample respectively for the left ear 68.3% and

19% of the sample. It was then determined that in the right ear, only 3.2% of cases presenting as a type C, and in the left ear 7.9% of the Type B and 4.8% of the type C tympanograms did not have fluid present during the operation for an overall accuracy of 83.76%. Tympanometry demonstrated a sensitivity of 85.85% and a specificity equal to 72.22% thus, demonstrating the value of tympanometry to evaluate the status of the middle ear when fluid is present (Anwar, 1969).

Audiologists can also be an integral part of the follow-up and management of pressure-equalizing tubes that are placed in children to assist with the negative effects of negative middle ear pressure. Shanks et al. (1992) assessed this by performing tympanometry on children diagnosed with OM with tubes. Pre- and postoperative measures of equivalent ear canal volumes in 334 children aged 6 weeks to nearly 7 years of age were obtained. The goal was to determine pediatric normative values to assist in determining if a TT is non-obstructed (patent) or obstructed. In the adult population, an abnormally large volume would be greater than 2.0 cm^3 suggestive of a perforation or patent TT but given the anatomical difference in the external and middle ear anatomy of children, this value cannot be applied to children. A criterion difference value of 0.4 cm^3 distinguished equivalent ear canal volume of pre- and postoperative measures. The false negative rate only reached 1.5% (10 cases) defined as labeling an intact TT as occluded or an occluded TT as patent. Outcomes suggest that if there is a 0.4 cm^3 difference observed during the follow-up process when comparing post-op from baseline pre-op volume measurements, then the TT is considered patent and fully functional. Further analysis also demonstrated that using 1.0 cm^3 as the lower-end cut-off for a non-obstructed TT yielded only 3% (22 cases) as a misdiagnosis of an obstructed TT in the presence of a patent TT. Therefore, a criterion value greater than or equal to 1.0 cm^3 was determined as an indicator of a TM perforation or patent TT in children aged infants to approximately 7 years of age (Shanks et al., 1992).

Acoustic Reflex Testing

Acoustic reflex testing represents a measurement of the acoustic stapedial muscle contraction, resulting in a direct change of sound flow energy through the middle ear naturally occurring in response to a loud stimulus. The existence of both ipsilateral and contralateral pathways allows for it to be measured which can be affected by a conductive loss when the stimulated ear is on the affected side (Musiek & Baran., 2020b). Marchant et al. (1986) described how CHL resulting from effusion could be detected through the assessment of the ipsilateral pathway revealing an elevated response level to elicit the reflex. In diagnosing fluid in the middle ear, observing a reflex threshold greater than 100 dB HL demonstrates optimal agreement with otoscopy and tympanometry measurements (Marchant et al., 1986). A cohort study by Ryding et al. (2002) assessed 113 children experiencing purulent AOM and allowed for a further analysis of 12 children with RAOM, one with a unilateral infection, classified in this study as 6 or more episodes of purulent AOM within 12 months. Elevated ipsilateral reflex responses were observed at two frequencies in the left ears and one frequency in the right ears suggestive of OM influence on the mechanics of the middle ear system (Ryding et al., 2002). A longitudinal investigation of health and behavior in a birth cohort yielded a sample of 631 children assessed at age 5, 7, and 9 for the degree of OM further placed into 3 groupings classified from most to least severe was conducted by Welch and Dawes (2006). Forty-four children were placed in group 1 defined as bilateral persistent OM, 190 children in group 2 experiencing unilateral persistent or transient OM with potential TM scarring, and 397 children in group 3 presenting with no type B, observed OM or scarring. At age 11 audiometric thresholds were obtained and subsequently at

15 years of age acoustic reflex testing of the ipsilateral and contralateral pathways was conducted. Groups 2 and 3 demonstrated little differentiation while Group 1 was elevated in comparison with a mean response 2 dB higher indicating a relationship between elevated ART later in life concerning OM severity (Welch & Dawes., 2006).

Wideband Acoustic Immittance

Wideband acoustic immittance (WAI) is a relatively new clinical method of measurement of middle ear properties (Grais et al., 2024). Including parameters of acoustic admittance, impedance, reflectance, and absorbance in response to a wideband click stimulus with energy ranging from 200 to 8000 Hz. The two most common ways to measure are power reflectance representing the ratio of reflected sound energy in comparison to the incident sound energy provided and power absorbance a simple ratio of 0 (all sound absorbed) to 1(all sound reflected). Measuring absorbance at multiple frequencies and plotting them into a 3D plot demonstrates information regarding absorbance, frequency, and pressure. Relative to differential diagnosis in insightful information plausible to the ability to assess the middle ear space status and ossicular chain function. Negative middle ear pressure will result in increased reflectance in the low-frequency range of 500 to 1500 Hz and an effusion result in increased reflectance in the higher frequency range. Therefore, providing information regarding the state of the middle ear if an OM episode is present (Grais et al., 2024).

A recent study conducted by Merchant et al. in 2021 aimed to understand the systemic effect of middle ear effusion volume on WAI with a population of 26 children recruited from Boys Town National Research Hospital with an effusion confirmed during the surgical procedure. Ultimately identifying that as the volume of effusion present in the middle ear space increases the absorbance is systemically reduced. Reduction in absorbance is observable across all frequencies but it is most noticeable from 1,000 to 5,000 Hz, especially as the volume of effusion increases. A trend of ambient absorbance measures demonstrates slightly higher absorbance around 4,000 specifically for full ears and those with partial peak pressure measures were higher than ambient (Merchant et al., 2021). Then in 2022, wideband acoustic immittance can be used conjointly with diagnostic prediction performance models to estimate the expected degree of hearing loss. A hybrid approach including both absorbance loss and ossicular loss in two different ways was able to predict air conduction thresholds within 5 dB of accuracy in a sample of 34 ears belonging to children ranging in age from 9 months to 11 years old (Merchant & Neely, 2023).

Otoacoustic Emissions

Musiek and Baran (2020b) describe otoacoustic emission measures as capable of providing information regarding the functionality of the outer hair cells in the cochlea and proves to be a helpful tool with differential diagnosis. The probe stimulus must be able to travel through the outer ear, middle ear, and inner ear for a response to be measured. Distortion product otoacoustic emissions (DPOAEs) are elicited by a nonlinear process within the cochlea because of the presentation of two stimulus tones resulting in the stimulation of a frequency resulting from the distortion product of the two. Measurement requires a forward and backward response transmission of the signal; therefore, a middle ear pathology will affect this transmission process. Transient evoked otoacoustic emissions (TEOAS) utilize a transient stimulus, such as a click, to evoke a cochlear response. Considered a broad-spectrum response and not representative of frequency-specific information. A response is considered either present or absent based on the relationship between the amplitude of the response signal measured and the noise floor, a repeatable response exceeding the noise floor is present (Musiek & Baran, 2020b).

A sample of 27 children (51 ears) from two otolaryngology clinics at Boys Town National Research Hospital with a recorded history of COM or CROM undergoing TT placement were analyzed along with a control group of 10 healthy children (17 ears) (Al-Salim et al., 2021). Participants were grouped by the appearance of the TM and effusion characteristics. Grouping by viscosity resulted in 1 purulent case, 27 mucoid cases, 3 serous cases, and 17 healthy control ears where DPOAES were present in 91.18% of controls, 0% with purulent, 14.99% with mucoid, and 38.10% with serous effusion. TEOAS were present in 92.4% of controls, 0% with purulent, 17.789% with mucoid, and 60% with serous effusion. Effusion volume was grouped by 19 full, 12 partial, 20 clear effusions, and 17 healthy ears. The controls revealed present DPOAEs in 91.18% of controls, 6.39% with full, 33.13% with partial, 71.67 with clear effusions, and TEOAS respectively 92.94%, 2.11%, 51.67%, and 70% (Al-Salim et al., 2021). Demonstrating that the more serious and greater amounts effusion the likelihood of obtaining OAE results diminishes with full effusion most likely to receive absent test responses.

Evoked Potentials

Electrophysical testing such as Auditory brainstem response (ABR), P300, long latency auditory evoked potentials (LLAEP), and frequency following response (FFR) can be used to analyze the CANS function (Colella-Santos et al., 2019). For this study 50 children aged 8 to 14 years old who had a history of OM and underwent tube placement as a treatment compared to 40 normal hearing and functioning children received a battery of electrophysical tests. Assessment of these children revealed latency delays and reduced amplitude for waves III and V of the ABR and a delay with reduced amplitude of P2, N2, and P300 responses. FFR also showed latency delays and a reduction of amplitude within the repones. This allowed the researchers to demonstrate that electrophysiologic potentials are suggestive that OM does have a negative effect on an individual's auditory abilities (Colella-Santos et al., 2019). Bone-conducted ABR may be a good way to assess the conductive components' function within the system and exploration of this topic was done by Seo et al. (2018). Bone and air conduction can both be used to determine the nature of hearing loss if present. Auditory brainstem response results may be indicative of fluid within the system and should be interpreted with care given the likelihood of measuring a stimulus artifact from the oscillatory motion of the skull itself. Additionally, embryonic tissue could still be present within the middle ear system, and it is suggested that 48 hours should be allowed for this to naturally clear before doing bone-conducted ABR testing. However, newborns in the neonatal intensive care unit experience a high incidence of OME and it has been suggested that performing bone-conducted ABR is useful as it provides information regarding any potential conductive elements present within the hearing system when behavioral responses cannot yet be consistently obtained (Seo et al., 2018).

Documentation

Rosenfeld et al. (2004) describe medical documentation to be essential in the referral process as it allows for the necessary information to be passed along to all providers treating an individual. This should be conclusive of the patient and family's medical history, current conditions, and impact of the condition on function, and most importantly clearly state the reason for the referral while being concise and accurate. The American Academy of Audiology acknowledges that the child and family initially will see a primary clinician for evaluation and may be referred out to an otolaryngologist, audiologist, or speech-language pathologist. The referring clinician should ensure the duration of effusion, any relevant information regarding the history of AOM or overall developmental status, and reason for referral, and a need for further evaluation or treatment. Documentation also works to ensure patient safety and can reduce the number of medical errors made. Management and treatment of OM are determined by the laterality of the effusion, nature of effusion, severity of symptoms, and overall development of the child. (Rosenfeld et al., 2004). More recently the recommendation has been updated to include a stronger recommendation for the use and documentation of effusive cases with pneumatic otoscopy and to include in the chart a medical record that counseling of the importance of follow-up visits with caregivers took place. Discussion with caregivers should include the necessity of ruling out a SNHL when the episode of OM resolves. The evident or potential impact on speech should also be included in these documentation processes to ensure the appropriate professionals can be involved and appropriate referrals occur. Also, important to include is the resolution, improved hearing, or improved quality of life (Rosenfeld et al., 2022).

Deficits in Caregiver Needs

Common themes throughout parental perspectives of otitis media were explored by Meherali et al. (2019) in a qualitative descriptive designed study aimed to obtain information on parental needs regarding AOM in which extensive interviews were obtained from 16 parental figures of children who sought emergency department care at a major Canadian urban center. A semi-structured interview was conducted in person or via telephone call with a length ranging from 8 to 40 minutes and the average duration was 19 minutes in which parents experiencing a child with an AOM episode were explored and parents were invited to express their general outlook on their experiences. Results will also be summarized below in Table 6. Parent reports aligned with incidence trends previously discussed with children aged 1 to 3 years old were more likely to have multiple episodes a year trending downwards with maturation. Younger children were also observed to be more irritable, often accompanied by inconsolable crying or screaming bouts. Seemingly linked with a flu or cold-like episode of AOM with associated pain and fever also leading to the emergency department visit rather than a primary care physician or a pediatrician. Within this sample size of 16 children according to these parent reports two children had a seizure which physicians linked to a high fever. A combination of parental decision and physician guidance resulted in 14 children utilizing an appropriate dose of acetaminophen (Tylenol) or ibuprofen (Advil) to monitor pain and fevers. Alternate symptom management methods that were reportedly utilized included sleeping with an extra pillow to elevate the head, massaging the ears, covering the ears when outdoors and when swimming, and 1 participant placed a clove of garlic in the concha area of the pinna. These methods were used for 24 to 48 hours on average before the parent sought further advice or treatment. Parent beliefs of AOM were skewed from factual evidence with a participant believing swimming was the cause, a mother who strictly breastfed her children thought they had gained immunity, and overall parents were not generally concerned with the effects of AOM. One parent was noted to have expressed concern for the long-term consequences of the decreased quality of hearing and not the infection itself. Six parents went along with physician recommendations or thought antibiotics would be appropriate and 4 parents were strongly against the idea of their child taking antibiotics with fear of antibiotic resistance. Twelve of these sixteen children were treated with some form of an antibiotic prescription and were provided to twelve children in the sample in which 4 parents were not satisfied and 6 of them were found to be an effective treatment approach. Thirteen caregivers reported that their physician had initially recommended the “watch and wait procedure” or it was used in combination with an antibiotic prescription the parent could choose to fill. Two of the initial emergency visits led to recurring cases ultimately resulting in PET placement by an ENT (Meherali et al., 2019)

Table 6

Common themes throughout parental perspectives of otitis media

Theme Description	Findings
1. Frequency of acute otitis media.	Larger variability ranging from 1 to 4 episodes a year in younger and 1 to 2 episodes a year in older patients.
2. Symptoms of acute otitis media by children and parents.	Common: • Otalgia, Fever, Inconsolable screaming or crying. Less common: • Tympanic membrane ruptured resulting in increased otalgia, screaming, and fluid drainage. Severe complications: • Seizure related to high fever.

Table 6 Continued

Theme Description	Findings
3. Acute otitis media Symptom management strategies.	Most common: • Age-appropriate dosage of acetaminophen (Tylenol) or ibuprofen (Advil) or alternating between an age-appropriate dosage of acetaminophen (Tylenol) and ibuprofen (Advil). Alternate strategies: • Elevating head, massaging ears, warm compress, garlic clove in the ear canal, and covering ears outside of the house, swimming, or bathing
4. Parent beliefs of acute otitis media.	• Bacterial origin • Environmental affluences including cold weather and water in the ears. • Breast-feeding creating immunity. • Lack of concern for long-term effects • Antibiotics best course of action. • Concern for antibiotic resistance

Table 6 Continued

5. Parental satisfaction with physician prescribed treatment.	• 40% of parents were pleased with prescription of antibiotics. • Few children were referred for further medical evaluation.
6. Acute otitis media impact on family's quality of life.	• Emotional impact and toll on caregivers. • Initial episodes are associated with increased fear and anxiety. • Disruption to daily routines. • Lost wages and daycare fines. • Lack of confidence on when to seek additional support or treatment.
7. Parent's source of information regarding acute otitis media.	• Pediatricians • Local emergency departments faculty • Internet

Note: Adapted from Meherali et al. (2019)

Overall, six major informational themes were identified regarding what information parents need and these are summarized in Table 7 (Meherali et al., 2019).

Table 7

Parental informational needs regarding Acute Otitis Media identified by parents.

Number	Topic
1.	How acute otitis media is caused.
1.	Signs and symptoms.
2.	What to expect from a typical acute otitis media episode.
3.	Ways and approaches to alleviate symptoms.
4.	Information about antibiotic treatment options.
5.	When to seek emergency treatment or further treatment.
6.	What or how otitis media is caused.

Note: Adapted from Meherali et al. (2019)

A further review of 21 articles investigated AOM and parental needs as well as their experiences throughout the treatment process. Parent informational needs were significantly unmet which resulted in deficits of informed decision-making within the treatment process overall negatively impacting the child and family's well-being (Meherali et al., 2021).

Another study conducted at Denver Health by Frost et al. (2021) also aimed to interview caregivers who had a child with a diagnosis of AOM within the last 2 years. A survey aiming to understand caregivers' knowledge about OM was sent out to 2,447 eligible caregivers of which 101 were returned. Risk factors were assessed and over half of respondents understood smoke exposure and sleeping with a bottle would increase the risk of AOM. More than 60% of caregivers understood breastfeeding over formula, influenza vaccines, and recommended pediatric vaccines helped to reduce AOM risk. Caregivers also tended to worry if antibiotics were not prescribed their child would be in pain longer, the infection would persist, and there would be the risk of permanent damage or hearing loss. Satisfaction with a delayed antibiotic regimen dropped by 13% among caregivers and over half of them reported dissatisfaction or little satisfaction with the suggestion of an observation period. Regarding length of treatment, caregivers had fewer opinions in which 70% responded that any length of treatment is fine if recommended by the physician. It is suggested that we need to help alleviate parental pressure and improve education for caregivers on the risks and benefits of each treatment option to help reduce misconception and guide a well-informed choice (Frost et al., 2021)

Multidisciplinary Team

Pediatric hearing loss and otitis media management require the involvement of multiple specialties to provide comprehensive care to children and their families. Children should be appropriately treated and monitored to adapt to any changes in the child's status and performance. Hawley et al. (2017) aimed to determine the utility of a multidisciplinary clinic approach to pediatric hearing loss to coordinate care for these children. This study did exclude OM and ETD patients but does provide insightful information on the management process of 41 children seen with suspected congenital or acquired hearing loss associated with microtia and/or atresia. This pediatric hearing management clinic was staffed with a team comprised of otolaryngologists, an audiologist, a speech-language pathologist, and a geneticist to provide a team-based approach treatment plan. Recommendations were made and the follow-through of caregivers was determined 72% saw an otolaryngologist, 92% saw a speech-language pathologist, and 73% saw an audiologist as recommended. Confirmation of hearing loss occurred in 37 of the children and 7 of the 32 MRI or CTs conducted demonstrated abnormalities. Twenty-six caretakers were advised to meet with a geneticist and 48% of those continued with testing allowing 1 child to be newly identified with a deficit in connexin 26 and 2. This approach also allows for appointments to be coordinated to fit into fewer overall visits and optimized provided communication. Thus, this approach demonstrates that a multidisciplinary approach to hearing loss in pediatrics could be beneficial in the diagnostic, treatment, and rehabilitation periods (Hawley et al., 2017). This could be useful if applied to OM as children could see nurses, primary care physicians, pediatricians, emergency department faculty, speech-language pathologists, audiologists, otolaryngologists, and pharmacists when experiencing OM.

Special considerations may be considered for certain conditions. Down syndrome is characterized by a third copy of chromosome 21 and is a more common congenital syndrome that has been closely associated with multiple comorbidities often requiring a multidisciplinary care team (Roux-Levy et al., 2021). Structural abnormalities closely associated with Down syndrome result in an increased incidence of OM, requiring continued management and treatment from an otolaryngologist and audiologist especially concerning TTs (Sait et al., 2022) Pierre Robin sequence is a rarer condition commonly associated with airway obstruction, difficulties with feeding, and hearing applicable to the scope of practice for an audiologist. These individuals are also more likely to experience episodes of serous OM as a result however, an audiologist will not be the only professional in these cases as far as management emphasizing a need for collaboration to provide the most efficient care (Glynn et al., 2011).

Summary

Clinical practice guidelines inform best practice methods for pediatricians, physicians, audiologists, otolaryngologists, and other medical professionals tasked with the evaluation and treatment of patients experiencing otitis media. Each guideline presents distinct definitions and manifestations of otitis media and its subtypes. Treatment options have been well explored to provide proper guidance in the selection of treatment routes, educate and guide caregivers through options, and provide ideal follow-up procedures. Proper assessment of hearing ability in children with otitis media is an integral process of assessing the medical treatment needs. Audiologists are involved with otitis media through audiometric testing, assessment of hearing function, assisting with intervention for hearing loss, and screening speech-language skills. Parent education is also provided by the audiologist through testing and can provide insightful information to caregivers. Audiologists provide counseling and interpretations for results of tests allowing parents to get a better understanding of how otitis media may be impacting their kid specifically. Utilizing a comprehensive test battery approach will allow for differential diagnostic information to be provided to all providers on a multidisciplinary team to enhance their understanding of otitis media. Children with otitis media are likely to be involved with more than one medical professional, especially if more invasive treatment options like pressure equalizing tubes are selected. Adequate communication and detailed documentation should exist between all providers to ensure optimized patient care. Parental perspectives are an integral piece to achieving a more holistic understanding of otitis media and how to approach interacting with those indirectly affected by the disorder. These perspectives offer medical professionals' insight into how to appropriately achieve a more patient-centered care approach within their practices by directly identifying needs based on experience and input from the child and family.

CHAPTER III

CRITICAL APPRAISAL OF THE RESEARCH AND FUTURE DIRECTIONS

Assessment of Current Practice Guidelines

Clinical practice guidelines related to otitis media include contributions from the American Academies of Audiology, Otolaryngology and Head-Neck Surgery, Pediatrics, and Family Physicians. These guidelines provide clear definitions and presentations of otitis media (OM) and its subtypes, treatment selection, counseling caregivers, and follow-up protocol recommendations. Parental education is highlighted and defined as being provided with all information regarding OM, treatment options, possible sequelae, follow-up requirements, and reasoning. Informed decision-making is key throughout this process for caregivers and clinicians hold responsibility for this. The American Academy of Otolaryngology—Head and Neck Surgery Guideline (2022) provides guardian-friendly layperson resources and education regarding otitis media basics, the subtypes, treatment options, and more. A diagnostic flowchart designed to guide clinicians through the diagnostic and treatment process can be accessed at https://aao-hnsfjournals.onlinelibrary.wiley.com/doi/10.1177/01945998211065662.

The current guidelines do not reference recent research investigating newer treatment techniques. It is unclear what triggers a review of practice guidelines, and whether they should be routinely updated on a time-based schedule or if they await significant advances in the field. There also appears to be a lack of consensus on the longevity of tubal treatments leading to the surgeon's best judgment being utilized (Michel et al., 2020). Lastly, the guidelines are not all in alignment, and not all related organizations endorse or support all the guidelines. This leads to conflicting information and decision-making for parents and caregivers. It may be useful in the future for multi-disciplinary practice guidelines to be developed and a consensus reached if possible.

Assessment of Parental Needs

Caregivers are tasked with the responsibility of making decisions throughout the management process of otitis media and require proper education and counseling to achieve this. Reports have shown that lack of knowledge results in increased anxiety, stress, levels of uncertainty, fear, poor management, and a negative impact on overall quality of life (Meherali et al., 2021). Parental figures report they often lack an understanding of how AOM is caused, its signs, symptoms, typical episode expectations, how to approach symptoms, antibiotic use, and when they need to seek further treatment (Meherali et al., 2019). More in-depth analysis revealed informational needs were not met often resulting in reduced informed decision-making processes for parents (Meherali et al., 2021). While the problems are well documented, the solutions to these challenges are not well researched.

Assessment of Audiological Tools for Otitis Media

Clinical audiologists can participate in the prevention, identification, and rehabilitation process relevant to OM (Ad Hoc Committee on Scope of Practice in Audiology, 2004). Hearing services that are documented in combination with multidisciplinary collaboration can lead to timely and effective management of otitis media to reduce risks previously discussed in Chapter 1. Therefore, audiologists can obtain differential diagnostic information crucial in teasing apart subtypes of otitis media. There is an extensive research database demonstrating that OM can be routinely detected and monitored with the use of wideband frequency immittance testing, however, there may not be equal access to care (Merchant & Neely, 2023). Wideband immittance machines are not commonly accessible in clinics so how it impacts patient care has yet to be explored.

Gaps in Existing Literature and Potential Future Directions

The existing literature surrounding otitis media provides a basic understanding of otitis media and its subtypes. Within the time this literature review was conducted few recent studies exist regarding the current epidemiology of otitis media. A more updated understanding of epidemiology within the United States and globally would allow for a better understanding of prevalence, cultural influence, and risk factors. Factors influencing otitis media have long since been explored with great understanding accomplished for some, but others require more solidifying research to reach conclusions. Racial, ethnic, and socioeconomic disparities have been identified to influence the prevalence of otitis media and treatment; however, more research needs to be conducted regarding unequal healthcare access or utilization of surgical therapy especially given the ever-changing scope of healthcare systems (D. F. Smith & Boss, 2010). When confounding factors such as marital status, number of children in the household, breastfeeding status, and maternal age are controlled for Black and Asian infants are less likely to be diagnosed with OM (Vernacchio et al., 2004). Genetic factors possibly contribute to the incidence of otitis media, but a higher volume of exploration would strengthen and solidify these findings (Kondyarpu et al., 2021).

Studies investigating otitis media knowledge and understanding in caregivers have been limited in size and variety of population. Levels of parental education have lacked a sense of control resulting in impacts not being fully understood (Meherali et al. 2019) or low participation from a population that is more female-driven (Frost et al., 2021). Larger scale studies with a well-balanced population with similar methods to those already in existence could provide a wider-scaled understanding of parent' understanding of otitis media and their needs educationally and throughout the treatment process. Recall bias should also be considered within these larger studies as parents may not accurately describe situations from the past. Future studies should also consider the impact that tubal intervention has on the quality of life for the child and surrounding family given the negative impacts of otitis media.

Short-term effects and implications of otitis media have also been well explored while long-term effects of otitis media have been suggestive of auditory processing difficulties indicating an impact on the central auditory nervous system. Further research is required regarding the long-term influences of fluctuating thresholds (Khavarghazalani et al., 2016) and unilateral episodes of hearing loss (Machado et al., 2020). Long-term effects of pressure equalization tubes on a child's development have yet to be explored in those children who are treated more invasively with surgical intervention as compared to less invasive treatment (if feasible).

Treatment considerations related to tympanostomy tubes have described which patients are candidates and when intervention is warranted, but there is a notable gap in research regarding how long tubes will be placed, especially for those with more recurrent conditions. Michel et al. (2020) investigated a generalized medical consensus that suggested a removal timeframe before around 2 to 3 years post placement ideally before the onset of complication including but not limited to otorrhea and formulation of granulated tissue which could contribute to further complications. Keep in mind most tubes will naturally extrude in most cases by this point in time. A surgeon's clinical judgment is used most often to determine the need for TT removal, given the lack of best evidence (Michel et al., 2020). Other gaps exist surrounding Eustachian tube dysfunction and its relationship to otitis media. Long-term effects lack adequate exploration regarding varying tube dilation approaches, streamlined therapy approaches to cleft lip or palate affecting the eustachian tube, and application of herbal remedies specifically through inhalation, homeopathic-based agents, and tubal stents (Teschner, 2016). Probiotic-based treatment approaches show promising evidence in the prevention and treatment of otitis media but effectiveness regarding bacterial involvement, systemic effects of the immune system through activation, and populations that are more prone to OM (Coleman & Cervin, 2019). Pressure-equalizing tubes constructed of biodegradable and absorbable materials in vivo require more research before clinical application within human subjects. Pressure equalizing tubes (PET) constructed of ply-bis(ethylene) phosphazene (PBE) and inserted into 55 ears of healthy guinea pigs demonstrating results of 53% tube disintegration rate in 30 days, and 75% in 60 days with no complications defined as an injection (inward tube movement) or inflammatory reactions. This raises the potential for promising results with Human subjects, but more research is needed to determine the disintegration rate to understand necessary patient-based adjustments to be further explored (D'Eredità et al., 2002). A biocompatible "On-command" tympanostomy tube that is dissolvable by the body is being investigated to mitigate the need for additional surgical intervention and anesthesiology. Current exploration in rats (Mai et al., 2017) and chinchillas (Wiedermann et al., 2017) has been promising for the concept but further research is needed to ensure effectiveness and safety amongst humans.

Summary Statement

An overview of ear anatomy and physiology provides a basis for understanding the general pathophysiology of otitis media. Factors that influence the risk of otitis media were reviewed. Audiologists are part of a multidisciplinary team that provides assessment of the auditory system to assist in the diagnosis of otitis media in children (and adults).

A comprehensive review of clinical practice guidelines for otitis media, clinical tools, treatment routes, and parental perspectives has demonstrated the importance of understanding this condition and its impacts. Ultimately, allowing for caregivers and parental figures to receive adequate education and guidance throughout the entire process to allow informed decision-making. Patient and family quality of life is important to ease any nervousness, anxiety, or fear they may be enduring throughout this experience. A deeper understanding of otitis media could be obtained through updated global and national epidemiological exploration, including investigation into racial and ethnic disparities, genetic factors, and a broader understanding of caregiver knowledge. Physicians and audiologists that better understand the long-term effects of otitis media, the risk of reoccurrence, and treatment options will help physicians and audiologists better inform parents and caregivers through family-centered caregiving.

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