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Different causes of ear infection and its management

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Abstract

The causes and incidence of ear infection are different worldwide. The high incidence rate of ear infection is found in Asia Pacific, South Asia and African region. The major cause of ear infection is bacteria, virus and fungi. People with seasonal allergies may have a greater risk of getting ear infections when pollen counts are high. Air pollutants, such as sulphur dioxide (SO_2), harm the mucociliary function of the Eustachian tube and increases middle ear mucus secretion. The highest incidence of ear infection occurs between the age of 6-24 month and then decreases with advancing age. Use of cotton buds is a dangerous habit and has a strong association with neurodermatitis and contact dermatitis of the external ear. Ear nose and throat (ENT) infections have been reported among flood victims**.** The most recent effort to improve middle ear drug delivery has focused on optimizing peptide sequences that are actively transported across the tympanic membrane. To treat ear infection antibiotic therapy is required otherwise may become worse or may lead to deafness. However, when the patient suffering from ear infection comes to physician must consider the wide variety of pathogens including bacteria, fungi and viruses. Severe illness or resistance to drug is caused by inappropriate antibiotic therapy. The ear infection should be treated earlier and properly to avoid further development of infection. The combination therapy is the most efficacious. Adenoidectomy is a procedure to remove the adenoids; these are glands at the back of the nose that help fight infections. However, if they become enlarged due to an infection, they can cause an earache and a build-up of fluid. For the control of ear infection preventative measures are important in limiting the impact of this disease.

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Introduction

Ear is the organ of hearing and balance which has three parts, such as outer, middle, and inner ear. The outer ear collects sound waves, which move through the ear canal to the tympanic membrane, commonly called the eardrum. The inner ear is filled with fluid, here hair like structures stimulate nerves to change sound waves into electrochemical impulses (Guyton, 1999). The middle ear cavity is located in the mastoid process of the temporal bone. The cavity extends from the tympanic membrane to the inner ear. It is approximately 2cm^3 centimeters in volume and is lined with mucous membrane. The middle ear cavity is actually an extension of the nasopharynx via the Eustachian tube (Masters *et al.,* 1960). Ear infections are of three types. The first type is Otitis externa that intricate the outer ear and ear canal. In external otitis, the ear is painful when touched and it's also called swimmers ear. Otitis media is the second type in which otitis media the ear is contaminated with fluid behind the ear drum, in the habitually air-filled in space of middle ear. The infection of middle ear is very common in childhood, sometimes requires a surgical procedure called myringotomy and tube insertion. Eosinophilic otitis media is a newly recognized entity causing intractable middle ear pathology. This condition is characterized by excessive accumulation of eosinophils in the middle ear cavity and is associated with persistent middle ear effusion. These patients usually suffer from bronchial asthma. These secretions are highly viscous and the middle ear mucosa appears pinkish in color (Lino *et al.*, 2005). The third one is Otitis internal; it involves the inner ear sensory organs. When the inner ear is inflamed, common symptom is vertigo, also called as labyrinthitis (Sabella, 2005). The ear infection is the most common infections of pediatrics. A complication of major ear infections such as Otitis media varies depending on the duration of microbial colonization, severity of infection and associated microorganisms. Depending on the clinical presentation, otitis media can be subdivided into 2 types such as chronic suppurative otitis media (CSOM) and acute otitis media (AMO) (Oni *et al.*, 2002). Another type such as otitis media with effusion (OME) is also common.

The OME occurs in the majority of patients with cleft palate. In these patients middle ear disease persists longer and leads to higher incidence of conductive hearing losses, language disability and cholesteatoma formation (Sheahan *et al.,* 2003). Acute otitis media is the most common bacterial infection among children and the most frequent reason for outpatient antibiotic therapy (Macaig and Hughes, 1995). Despite proper antibiotic treatment, middle-ear effusion may persist for weeks or months (Mandel *et al.*, 1982). Adults make up less than 20% of patients presenting with acute otitis media. AOM leads to ear pain in young children and this may result in pulling at the ear, increased crying, and poor sleep while other features are fever and loss of appetite (Del-Mar *et al.*, 1997). Poverty status has long been recognized as being associated with a higher incidence and severity of recurrent AOM. The likely factors involved include crowding, poor hygiene, nutritional status, limited access to medical care and medications (Vakharia *et al.*, 2010).

Suppurative chronic otitis media

This happens when there is a hole in the eardrum and an infection in the middle ear. Cloudy and sometimes foul-smelling fluid drains out through the opening (Sharma *et al.,* 2004).

Chronic otitis media with cholesteatoma

A persistent hole in the eardrum sometimes can lead to a cholesteatoma, a growth (tumor) in the middle ear made of skin cells and debris. A cholesteatoma can also form when there is no hole, but the Eustachian tube is blocked. The exact cause is not known, but the eardrum is intact. Cholesteatomas can cause hearing loss and can lead to infection which can cause ear drainage. Cholesteatomas will grow large enough to erode the middle ear structures and the mastoid bone behind the middle ear (Laza and Enciu, 2019)

Causes of ear infection

Ear infection can be caused by bacteria, viruses and fungi. The major cause of ear infection is bacteria such as *Pseudomonas aeruginosa, Staphylococcus aureus, Proteus mirabilis, Klebsiella pneumonia and Escherichia coli* which are found in the skin of the

external ear and can enter into the middle ear through a chronic perforation (Bluestone and Klein, 1990). *Pseudomonas aeruginosa* is the most common pathogen causing ear infection. Antibiotic therapy is required to treat ear infection otherwise condition may become worse or may lead to deafness. However, the presence of fungi can be due to the treatment with antibiotic ear drops, which causes suppression of bacterial flora and the subsequent emergence of fungal flora. This probably increases the incidence of fungal superinfection, and even the less virulent fungi become more opportunistic (Koopman *et al.*, 2008). However, when ear infection patient comes to physicians must consider the wide variety of pathogens including bacteria, viruses and fungi then treated with respect to the pathogen causing infection. Inappropriate antibiotic therapy may cause severe illness or resistance to drug (Tanno *et al.*, 1999).

Symptoms of ear infection

Symptoms of ear infection appear mostly after 2 to 7 days of infection. The main symptom is feeling of pain in ear, other symptoms include loss of appetite, fever, vomiting, fluid draining by ear, fussiness, clumsiness and ringing in the ear (Morris, 2004).

Pathogenesis of ear infection

Many factors like Eustachian tube dysfunction and susceptibility to upper respiratory tract infection may contribute to pathogenesis of otitis media (Ahmad *et al.*, 1999). Otitis media is an inflammatory condition of the middle ear that is initiated by functional or mechanical obstruction of the Eustachian tube. It leads to alteration in the partial pressure of middle ear gases, resulting in negative middle ear pressure. Nasopharyngeal bacteria may invade the middle ear space via the obstructed Eustachian tube and replicate within the serous middle ear fluid. Bacterial and inflammatory host cell products are released into middle ear effusion and tissues, attracting peripheral blood leukocytes and leading to a cascade of acute inflammatory events that result in symptomatic acute otitis media (Kathleen *et al.*, 1999). Eustachian tube dysfunction is usually triggered by a viral process. Such dysfunction is further complicated in early infancy by the horizontal anatomy of the tube, which makes middle ear fluid flow more stimulating. Usually a viral upper respiratory tract infection precedes the onset of middle ear effusion (MEE). A viral infection increases mucus production in the nasopharyngeal region, creating inflammation in the area. This eventually results in closure of the Eustachian tube and buildup of fluid behind the tympanic membrane (TM). When OME develops, the middle ear fluid is sterile, but secretions from the nasopharyngeal area are not sterile. Microorganisms present in the nasopharynx reflux into the middle ear space when the Eustachian tube temporarily relaxes. This can result in bacterial adherence and colonization, which eventually can develop into the inflammatory process of AOM (Abrahim and Labbok, 2011).

Epidemiology of ear infection

In the United States, the annual cost of ear infection has been estimated to exceed 3.5 billion (Stool and Field 1989). Although acute ear infection is generally considered a bacterial infection, there is sufficient evidence that respiratory viruses have a crucial role in the etiology and pathogenesis of this disease (Ruuskane *et al.*, 1991). The etiologies and prevalence of ear infection are different in different geographical areas (Brook and frazier, 1996). According to World Health Organization (WHO) survey, countries can be grouped into those having low ear infection when a prevalence rate of ear infection among children is between 1-2% and high when it is 3-6%. Ethiopia belongs to the latter category (WHO, 2004). It is thought that between 50% and 85% of children experience at least one episode of acute otitis media by 3 years of age with the peak incidence being between 6 to 15 months (Klein, 2015). According to the WHO estimates of 2015, over 5% of the world's population (328 million adults and 32 million children) had disabling hearing loss. The highest prevalence is found in the Asia-Pacific, South Asia, and Sub-Saharan African regions. Half of all cases of hearing loss are avoidable through primary prevention while many can be treated. A leading cause of hearing loss in younger ages, particularly in low- and middle-income countries, is untreated ear

infections, often with discharge from the ear. Vaccine-preventable infectious diseases such as rubella, meningitis, measles, or mumps can also lead to hearing loss (Fauci *et al*., 2008).

Risk factors of ear infection

There are various risk factors that makes person more prone to ear infection which intricate mainly the age factor because children ages 3 years or younger have smaller Eustachian tube than adults so that are more prone to ear infections. Another factor such as congenital problem makes person acquiescent to ear infection and it was also seen that the immune compromised individuals are also at high risk of ear infection problems (Quinn *et al*., 1994).

Economic and social condition role in ear infection

The place of residence can play an important role in the ear infection rate due to the different economic and social conditions. The frequency of villagers and urban residents referral for the diagnosis and treatment of ear infections depends on various conditions, including attention to their illness, access to health care facilities, and the presence of specialists in private clinics. In a survey, urban residents were more likely to refer to the clinics for the sake of ear infections, with a rate of 77.59%-86.3% in urban areas and 17.5%-22.41% in rural areas have been reported (Mahdavi *et al*., 2015).

Ear infection over the age

Ear infection continues to be a common health problem worldwide. It is predominantly a disease of young children. The highest incidence of ear infection occurs between the age of 6-24 month and then decreases with advancing age. However, the disease does occur in older children, teens, and adults (Telle *et al.,* 1989). The lowest frequency was observed for the patients aged between 50 and 59 years (Kochak *et al*., 2004).

Ear infection in gender

Ear infection accounts for approximately 22 million visits to a physician each year. For some unknown reasons ear infection seems to occur more often in males than in females (Klein, 2015).

Ear infection in breast feeding children

Human milk is a biologically active substance containing antimicrobial, anti-inflammatory, and immunomodulatory agents that function to compensate for the physiologic immaturity of the infant immune system. Breast feeding likely protects against ear infection through the action of maternal antibodies against pathogens (Labbok *et al*., 2004). Recent evidence also indicates that human milk modulates the infant's own humoral immune response to common ear pathogens by stimulating the production of IgG antibodies. Breast feeding for 3 months or more is associated with a decreased risk of AOM in infants (Juson *et al.,* 2006).

Bottle feeding effect on ear infection

There is also indication that the physics of bottle feeding play a role in otitis media risk. A firm tongue-to-palate swallow, which is seen in breastfeeding, is suggested as necessary for the aeration of the Eustachian tube (Mew *et al.,* 1992). Pressure readings taken during feeding with standard no vented and under vented bottles have revealed that negative intra-tympanic pressure is generated in the infant due to the transmission of negative pressure from the bottle to the middle ear. This negative pressure may in turn contribute to Eustachian tube dysfunction, predisposing bottle-fed infants to otitis media. This effect was not observed in fully ventilated bottles, which produce suck and swallow actions more similar to those of breastfeeding infants (Brown & Magnuson, 2000). As the use of a supine feeding position may allow liquid to enter the middle ear (Tully *et al*., 1995).

Seasonal effect on ear infection

Although the role of the season in ear infection was more frequent in the autumn (57.3%) than in other seasons, Meanwhile the lowest infection was observed in the spring (16%). Ear infections are most common during the fall and winter. People with seasonal allergies may have a greater risk of ear infections when pollen counts are high (Akhi *et al.,* 2001).

Air pollution effect on ear infection

There is growing evidence that air pollution exposure is associated with asthma and allergies in children

(Bowatte *et al.,* 2015). Air pollutants such as particulate matter (PM), trigger oxidative responses and inflammation in lung epithelium lead to asthma and allergies. Animal studies provide evidence that air pollutants, such as sulphur dioxide (SO_2) impair the mucociliary function of the Eustachian tube and increase middle ear mucus secretion (Ohashi *et al.,* 1989). The upper respiratory tract, including nose and upper airway, play an important role in filtering and conditioning inspired air. The nose and mouth are the main entry points for inspired air and are connected via the nasopharynx. The nasopharynx connects to the middle ear via the Eustachian tube, located at the back of the nasopharynx. This direct connection to the middle ear creates a link between inspired air and the middle ear. Larger airborne particles, and some liquid are dissolved or otherwise trapped by the nasal mucosa and transported to the back nasopharyngeal cavity and enter the airways and lungs. Given the direct connection between the nasopharynx and middle ear, these pollutants may interact with the eustachian tube epithelium. This epithelium includes columnar ciliated cells with motile hair like appendages called cilia that beat rhythmically in the direction of the nasopharynx and are involved in mucociliary clearance and drainage of middle ear fluid. The Eustachian tube also allows air exchange and pressure balance. When inflammatory agents such as viral or bacterial pathogens, allergens, pollutants and other irritants interact with the nasal mucosa, resulting inflammation can narrow or block the Eustachian tube. Dysfunction in the Eustachian tube can lead to middle ear fluid stasis and subsequent middle ear infection (Jones, 2012).

Cotton bud effect on ear infection

Use of cotton bud is not only unnecessary but potentially dangerous. Ear injuries caused by the use of cotton bud are commonly seen in ear, nose and throat (ENT). It can lead to infection, retention of the cotton bud, wax plug impaction, discomfort, deafness and vertigo, injury to the external auditory canal or perforation of the tympanic membrane, facial nerve paralysis and inner ear damage (Hobson and Javy., 2005). A large number of patients report daily to doctors and otolaryngologist with the complaint of itching and urge to scratch their external ears. Majority of them are the users of cotton buds. Uses of cotton bud are a dangerous habit and have strong association with neurodermatitis and contact dermatitis of the external ear. Cotton bud is also associated with acute otitis external, rupture of tympanic membrane and perichondritis in few patients (Loock *et al.,* 2008).

Head phone role in ear infection

The use of headphone has been thought to create aural hygiene problems and infection in the ear canal. Wearing headphones or earplugs has been suggested as a possible predisposing factor for external ear canal infection since their use can increase the temperature and humidity of the canal, create the potential for skin abrasion and provide a vehicle for the introduction of organisms into the canal skin. Customer service representatives function as telephonists, who uses headphone to receive phone calls from Celcom customer. They work in shift of 8 hours with one-hour break. Therefore, all of them wear headphones and receiving calls continuously for 7 hours. Many incidences of ear problems have been reported among these customer service representatives (Enturia *et al*., 1980).

Flood effect on ear infection

Onset of flood results in an even higher infectious diseases burden, both in absolute and relative term. Flooding is associated with an increased risk of infection. The risk factors that would include are population displacement, inadequate shelter conditions, degree of overcrowding, drinking contaminated water, improper sanitation, an underlying health status of population, malnutrition, local diseases ecology and difficulties in accessibility of health care services (Watson *et al*., 2007). Provision of relief must consider the situation of infectious diseases in areas where flood has potential risk to human (Kondo *et al*., 2002). Ear nose and throat (ENT) infection 5% while eye infections (acute conjunctivitis) have been reported 7% among flood victims (Zeeshan *et al*., 2011).

Diagnoses of ear infection

There are many ways to diagnose the ear infection which include different test. The most commonly preferential test includes pneumatic otoscope (the air passed to the ear by otoscope in order to see the movement of ear drum) other diagnostic tools include hearing test, tympanometry and blood tests (Hariharan *et al*., 1995). Blood test for diagnosis is only preferred when the immunodeficiency is a major cause of infection in ear. Some defensive steps could be taken in order to prevent ear infection which includes immunization, proper child care, avoiding smoking and maintenance of hygiene conditions (Tagg and Dierksen, 2003).

Detecting ear infection using smartphones

Researchers at the University of Washington have created a new smartphone app that can detect fluid behind the eardrum by simply using a piece of paper and a smartphone's microphone and speaker. The smartphone makes a series of soft audible chirps into the ear through a small paper funnel and, the chirps are reflected back to the phone. The app determines the likelihood of fluid present with a probability of detection of 85%. This is on par with current methods used by specialists to detect fluid in the middle ear, which involve specialized tools that use acoustics or a puff of air (Justi *et al.,* 2019).

Treatment of ear infection

Use of a topical ontic preparation without culture is a reasonable treatment approach for patients who have mild symptoms of otitis external. If the tympanic membrane is intact and there is no concern of hypersensitivity to aminoglycosides, a neomycin/ polymyxin B/hydrocortisone ontic preparation would be a first-line therapy because of its effectiveness and low cost. Ofloxacin and ciprofloxacin/dexamethasone (Ciprodex) are approved for middle ear use and should be used if the tympanic membrane is not intact or its status cannot be determined visually (Rosenfeld *et al.,* 2006). Serious infections caused by Gram-positive bacteria are increasingly difficult to treat because of pathogens such as methicillin-resistant *Staphylococcus aureus* (MRSA), and penicillin-resistant *Streptococcus pneumoniae* (Menichetti, 2005). *Pseudomonas aeruginosa* could cause very severe illness for immune-compromised patients and may be it becomes life threatening if not treated on time properly. According to some studies other pathogens such as *Streptococcus pneumonia* and coagulase negative *Staphylococcus* are highly sensitive to penicillin's. *Proteus miabilis*, *Staphylococcus aureus, Klebsiella* pneumonia and *Pseudomonas aeruginosa* are highly sensitive to cephalosporins. *Pseudomonas* species are highly sensitive to aminoglycosides while *Proteus vulgaris* is highly sensitive to carbapenems. Combination therapy is the most efficacious therapy and could treat ear infection quickly and properly with less chances of development of resistance. It could also be treated with single antibiotic therapy like cephalosporins but infections caused by *Pseudomonas* species couldn't efficaciously be treated by cephalosporins but it requires combination of antibiotic therapy (Tano *et al*., 1999).

The AOM and CSOM heritability estimates of 40%–70% have been reported; however, the majority of genes underlying this susceptibility are yet to be identified. It is likely that there are mixtures of innate defense molecules which may or may not become defective, leading to otitis media susceptibility. Potential therapeutic targets are the genes regulating mucin expression, mucus production, and host response to bacteria in the middle ear. Genetics research has also identified the important role for hypoxia in OME, and this may (partly) explain the effectiveness of ventilation tubes, which would relieve any hypoxia in the middle ear (Tasker *et al*., 2002). Mouse models have been used to demonstrate a role for hypoxia inducible factor and vascular endothelial growth factor (HIF-VEGF) signaling pathways in the pathogenesis of OME, and these may be potential future therapeutic targets for the treatment of OME (Cheeseman *et al*., 2011).

Delivery of drugs through transtympanic route

Trans-tympanic delivery offers a potentially more viable option for local drug delivery for the treatment

of OM in the outpatient setting. The Wright group performed the first clinical trial to demonstrate safe and efficacious treatment with a therapeutic bacteriophage preparation (Biophage-PA) against *P. aeruginosa*. The ability of a phage to pass through the tympanic membrane appears to be determined by the amino acid sequences that are displayed on the surface of the phages (Wright *et al.*, 2009)**.** The most recent efforts to improve middle ear drug delivery have focused on optimizing peptide sequences that are actively transported across the tympanic membrane (Kurabi *et al.*, 2018).

Duration of antimicrobial therapy for ear infection

Ten-day antimicrobial treatment courses are appropriate for children younger than two years of age, children with frequent recurrent AOM or otitis media with perforated tympanic membrane, because these children are at increased risk of treatment failure (Mccaig and Hughes, 1995). The benefit of the longer course may partly come from the child being in a "prophylaxed state" should he or she develop a new upper respiratory tract infection within 10 days of AOM diagnosis. However, if the child develop antimicrobial-related adverse events between day 5 and day 10, it is reasonable to stop antimicrobials rather than prescribing an alternative antimicrobial drug (Pichichero *et al.,* 2001).

Role of Adenoids

The adenoids are pads of tissue located at the back of the nasal cavity. They react to passing bacteria and viruses and play a part in immune system activity. The adenoids can sometimes trap bacteria, however, this can lead to infection and inflammation of the Eustachian tubes and middle ear. The adenoids are close to the openings of the Eustachian tubes, and if they swell, they can cause the tubes to close. Children have relatively large adenoids that are more active than those of adults. These might make children more likely to contract ear infections (Harmes *et al.,* 2013).

Adenoidectomy in ear infection

An adenoidectomy is a procedure to remove the adenoids. The adenoids are glands at the back of the nose that help fight infections. However, if they become enlarged due to an infection, they can cause an earache and a build-up of fluid. If this happens regularly, a doctor may perform an adenoidectomy to help reduce chronic ear infections. According to 2014 study, children under the age of 2 years with recurrent acute otitis media (AOM) and those who are over the age of 4 years with persistent otitis media with effusion (OME) are most likely to benefit from adenoidectomy (Byars *et al.,* 2018).

Prevention of ear infection

Preventative measures to control ear infection are important in limiting the impact of this disease, associated antibiotic prescription, and emerging bacterial resistance. Promising candidate antigens for vaccination have been identified in *S. pneumoniae* (the commonest cause of ear infection), nontypeable *H. influenza*, and *M. catarrhalis*. The pneumococcal conjugate vaccine was primarily developed to address invasive pneumococcal disease (ie, pneumonia), and has proven useful in targeting the commonest cause of ear infection (Pelton *et al.,* 2013).

Conclusion

Middle ear infection such as otitis media is frequently encountered ear infection throughout the world. Children under five year age are most affected by ear infections. This may be due to different factors such as anatomy of Eustachian tubes, the nutritional status of the children and other health problems like upper respiratory tract infections which are common in children. The place of residence can also play an effective role in ear infection. Ear infections are most common during winter season. A large number of patients complain of itching and urge to scratch their external ears. Majority of them are users of cotton bud. However many parents are not aware of its presence in the affected children. Low education levels and being exposed to household smoke are risk factors. Common symptoms were earache, ear discharge and hearing impairment, fussiness, clumsiness and scandal of ringing in ear. *Pseudomonas aeruginosa* is the very most common pathogen causing ear infections.

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