In this article...

- The structure of the external, middle and inner ears
- Understanding the mechanisms of hearing and balance
- Ear problems and associated health conditions

The structure and function of the ear and its role in hearing and balance

Nurses need to understand the structure and the function of the ear, as they may have to care for patients who have chronic ear problems and across many different specialties, in both hospital and community settings.

The ear is divided into three interconnected sections: external, middle and inner ears (Fig 1). While the external and middle ears are mainly concerned with the transmission of sound, the inner ear contains the cochlea – often called the organ of hearing – and also houses the body’s organ of balance.

The transmission of sound takes place in the external and middle ears.

The inner ear houses the cochlea (organ of hearing) and the peripheral vestibular system (organ of balance).

Ear problems can be associated with other health conditions and patients with chronic ear problems are seen across many nursing specialties.

The structure and function of the ear and its role in hearing and balance.

Author
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Abstract
The ears provide the important functions of hearing and balance. Ear problems can be debilitating for patients and may also be associated with other health conditions. Nurses may be caring for patients with chronic ear problems across many nursing specialties in both hospital and community settings, and they need to understand the structure and function of the ear.

Citation

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- Understanding the mechanisms of hearing and balance
- Ear problems and associated health conditions

Key points

- Hearing and balance are the two main functions of the ear
- The transmission of sound takes place in the external and middle ears
- The inner ear houses the cochlea (organ of hearing) and the peripheral vestibular system (organ of balance)
- Ear problems can be associated with other health conditions and patients with chronic ear problems are seen across many nursing specialties

Nurses need to understand the structure and the function of the ear, as they may have to care for patients who have chronic ear problems and across many different specialties, in both hospital and community settings.

The ear is divided into three interconnected sections: external, middle and inner ears (Fig 1). While the external and middle ears are mainly concerned with the transmission of sound, the inner ear contains the cochlea – often called the organ of hearing – and also houses the body’s organ of balance.

The ear development

The ear starts to develop as early as in the sixth week of pregnancy. During foetal development, the pinna (the visible part of the ear) forms from little bumps (hillocks) on the side of the head, which grow and fuse. Sometimes the pinna fails to develop fully – known as microtia – and in some babies the ear canal may also be absent.

Preauricular sinus is a common congenital abnormality in which complete fusion of the hillocks fails to occur; it often appears as a tiny skin-lined hole in front of the upper ear, where the cartilage of the ear meets the face (Fig 2). If both sides of the head are affected, it is often considered to be an inherited abnormality.

Failure in the development of the antihelix – a curved prominence of cartilage that is parallel with, and in front of, the helix or outer rim of the ear (Fig 2) – leads to protruding ears; this is also often an inherited trait.

External ear

The external ear canal, sometimes referred to as the external auditory canal or external auditory meatus (EAM), is lined with skin and is approximately 2.5cm long. In continuation of the pinna, the outer third is composed of cartilage; skin lining this cartilage has hair follicles and wax-producing glands, which are a combination of ceruminous and sebaceous glands.

The sebaceous glands secrete an oily substance called sebum into the root canal of the hair follicles, while the ceruminous glands are modified apocrine sweat glands, which open into the base of the hair follicles and produce a moist white secretion that darkens and thickens as it dries, becoming sticky. It is estimated that the ceruminous glands and hair follicles develop when the foetus is about five months old (Szymanski and Geiger, 2020).
Unlike the rest of the body, where skin grows from the basal layers towards the surface, the skin in the external ear canal migrates from the tympanic membrane towards the entrance; the rate of migration varies between individuals. The shedding of migrated skin mixes with secretions from the glands to form wax; any collection of migrated skin mixes with secretions varies between individuals. The shedding towards the entrance to assist the migration of wax out of the external ear canal from bacterial and fungal infection; in the outer third of the canal, the hairs lift the wax slightly away from the skin to prevent skin irritation (Harkin, 2019).

As the glands are only located in the outer third of the external ear canal, this is the only place in the canal that wax should be seen. Short hairs are located above the glands and are projected towards the canal entrance to assist the migration of wax out of the ear canal; they protect the ear canal by trapping dust and debris and discouraging anything from entering the external ear canal. Wax is slightly acidic and protects the external ear canal from bacterial and fungal infection; in the outer third of the canal, the hairs lift the wax slightly away from the skin to prevent skin irritation (Harkin, 2019).

The inner two-thirds of the ear canal are housed in the temporal bone, with the skin tightly adhering to that bone; the diameter of the ear canal varies between individuals and races (Ludman and Wright, 1998). The ear canal travels downwards and slightly forwards into the skull, with a slight narrowing and bend at the junction of the cartilage and bone of the skull. At the end of the external ear canal is the tympanic membrane (eardrum), which lies at a slant, leaving a recess towards the anterior wall of the ear canal. The pinna needs to be moved upwards and outwards in adults (downwards and backwards in children) to be able to see down the canal to the tympanic membrane.

The tympanic membrane (Fig 3) divides the external ear from the middle ear; it is slightly oval in shape and approximately 9-10mm at its largest diameter. The pars tensa (Fig 4) makes up the majority of this membrane and is situated at the lower part of the tympanic membrane. It comprises three layers:
- Epithelium continuous with the external ear canal;
- Fibrous middle layer;
- Mucosal layer, lining the whole of the middle ear and upper respiratory tract.

Middle ear

The middle ear has an irregular shape and is lined with mucosa. Although commonly thought of as an air-filled space, it is filled with nitrogen-rich gas (Hussain, 2016).

The roof of the middle ear has a thin plate of bone called the tegmen tympani separating it from the meninges and temporal lobe of the brain. Its floor is formed by the roof of the jugular fossa and is close to the internal jugular vein and internal carotid artery. The proximity of the vein and artery means people can complain that...
they sometimes hear blood pumping in their ear.

The opening for the eustachian tube is on the anterior wall of the middle ear. This tube is part cartilage and part bone and connects the middle ear with the nasopharynx, which is located in the post-nasal space.

To optimise the environment for hearing, the middle-ear space should have air equal to atmospheric pressure. The eustachian tube allows for air entry and exit to the middle ear, which helps equalise the air pressure. The muscles of the soft palate are attached to the cartilage portion of the eustachian tube and contract on chewing, swallowing, and yawning, allowing air to pass into the middle ear through the opened tube. This process varies between people, but is estimated to take 0.15–0.34 seconds (Ludman and Wright, 1998).

Children’s eustachian tubes are shorter and more horizontal due to the smaller size of the skull and are less efficient at equalising pressure. As the head grows and the skull enlarges, the eustachian tube becomes more vertical and the efficiency of equalisation of pressure in the middle ear improves.

Inner ear
The inner ear consists of:

- The cochlea (organ of hearing);
- The peripheral vestibular apparatus (organ of body balance).

Cochlea
The cochlea is a dense, snail-like structure of two and three-quarter turn, which lies sideways and houses the organ of Corti. Its spiral canal varies in length from 29mm to 40mm and is divided into three compartments by partitions of bone and membrane. The upper (scala tympani) and lower (scala vestibule) compartments are filled with a fluid called perilymph; the middle compartment (scala media) is filled with a fluid called endolymph.

The organ of Corti is located on the lower membrane (basilar membrane) of the scala media and consists of cells with hair-like projections, connecting with the terminal ends of the auditory nerve. Each projection responds to different sound frequencies, with high frequencies located at its base and low frequencies towards the tip of the spiral canal (Hussain, 2016).

The first turn of the canal bulges into the middle ear and is called the promontory; the outline of this can often be seen when viewing the tympanic membrane with a microscope.

How we hear
The primary function of the middle ear is to convert air vibrations, which have been channelled down the external ear canal to the tympanic membrane, into fluid vibrations in the cochlea.

The three smallest bones in the body – the malleus, incus and stapes (Fig 1) – are located in the middle ear. These are known collectively as the ossicles and are vital to hearing.

The malleus lies high in the middle ear, suspended by a ligament, and its head articulates with the body of the incus by a synovial joint. Although the lateral process of the malleus is the most-prominent point visible on the tympanic membrane, the incus can often be seen during otoscopy. The incus articulates with the stapes, and the footplate of the stapes sits in the oval window at the base of the cochlea. The stapes measures, on average, 3mm long and 1.4mm wide; it is attached to the oval window by a ligament.

Sound waves travel along the external ear canal and cause the tympanic membrane to vibrate. The embedded lateral process of the malleus causes the vibrations to continue across the ossicles to the footplate of the stapes. The middle ear reduces the loudness of sound partly by transferring the medium of sound from air to fluid from the ossicles to the cochlea but also by the function of the ligaments. Sound waves...
The importance of the ear

Problems with hearing or balance can be extremely debilitating. Hearing connects people socially and a person’s ability to balance and move around safely helps maintain independence.

Although the ear is a relatively small structure, it is served by five cranial nerves:
- Trigeminal nerve (fifth cranial nerve);
- Facial nerve (seventh cranial nerve);
- Vestibulocochlear (eighth cranial nerve);
- Glossopharyngeal (ninth cranial nerve);
- Vagus (tenth cranial nerve).

During an ear examination, stimulation of the auralc branch of the vagus nerve can cause the patient to cough; this is called the Arnold’s reflex (Ryan et al, 2014).

The shared nerve supply between the ear and other parts of the head and neck means inflammation or other pathology in these regions can cause ear pain. Ear problems are also associated with a range of other conditions and can affect patients across different nursing specialties (Table 1).

Conclusion

Although the ear is small in size, it is essential for hearing and balance, and problems of the ear can be linked to other conditions. Understanding the structure and function of the ear will help nurses to pick up problems early and improve the care of patients with chronic ear problems and other associated health conditions. NT

<table>
<thead>
<tr>
<th>Specialty</th>
<th>Conditions and associated ear problems</th>
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<tbody>
<tr>
<td>Diabetes</td>
<td>Diabetics can result in neuropathy along the auditory nerve as well as retinopathy; people with diabetes also have ear wax at a higher pH (normal pH is 4), which can predispose them to external ear infections (otitis externa).</td>
</tr>
<tr>
<td>Neurology</td>
<td>Neurofibromatosis is associated with schwannomas (tumour of the nerve sheath), which can affect the vestibulocochlear nerve. Meningitis and brain abscess are rare, but can occur as a result of severe middle-ear infections. Degeneration of the cervical spine can cause referred pain in the ear.</td>
</tr>
<tr>
<td>Older adults</td>
<td>Degeneration of the hairs in the cochlea naturally occurs with age. It is estimated that there are &gt;12 million deaf and hard-of-hearing adults in the UK and that, by 2035, a fifth of the population will be affected (bit.ly/ActionHearing). Hearing loss increases the likelihood of older adults having accidents at home, as it can cause distraction and is often associated with impaired balance.</td>
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<tr>
<td>Mental health</td>
<td>Research shows a link between hearing loss and mental health: people with hearing loss are more likely to experience emotional distress, loneliness and depression and are twice as likely to develop dementia (Nakashima et al, 2016).</td>
</tr>
<tr>
<td>Dermatology</td>
<td>As the external ear is lined with skin, patients with skin conditions, such as Darier’s disease, can experience blocked ears caused by skin debris building up in the external ear canal.</td>
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<tr>
<td>Learning disability</td>
<td>There is a link between overproduction of wax and learning disability (Schwartz et al, 2017); this increases the risk of wax impaction, which can cause hearing loss, vertigo, tinnitus, external ear infections or pain.</td>
</tr>
<tr>
<td>Dental</td>
<td>Assessing earache should include questions on dental health and general health and wellbeing. Establishing the origin of ear pain will ensure referral to the most appropriate specialty. The ear is the closest structure to the temporomandibular joint, so ear pain may signal a dental problem.</td>
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<tr>
<td>Immunology</td>
<td>Patients who are immunocompromised have a higher risk of developing ear infections.</td>
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<tr>
<td>Trauma</td>
<td>The perilymph in the inner ear communicates with cerebrospinal fluid; hearing and balance can be affected by a severe electrolyte imbalance. Patients with head injury will always have an ear examination as the tegmen tympani separating the middle ear from the skull can fracture, and blood can often accumulate in the enclosed middle-ear space as a result of bleeding from a skull-based fracture.</td>
</tr>
<tr>
<td>Oncology</td>
<td>Patients who have tumours in the head and neck region can complain of referred pain in the ear. Some drugs used in chemotherapy can cause irreversible damage to the hearing nerve (vestibulocochlear eighth cranial nerve).</td>
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</tbody>
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References