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 interconnecting 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.

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).

Keywords

Ears/Hearing/Balance/Anatomy/Physiology

This article has been double-blind peer reviewed

Key points

Hearing and balance are the two main functions of the ear

The ear is divided into three parts: the external, middle and inner ears

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

Author

Harkin H is ear, nose and throat clinical nurse specialist, Ear, Nose and Throat Outpatient Department, Guy’s and St Thomas’ NHS Foundation Trust.

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

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; the rate of migration migrates from the tympanic membrane. The pinna needs to be able to see down the canal to the tympanic membrane.

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 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 3) 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.

The pars flaccida is a triangular area above the pars tensa, which lacks a fibrous layer. This makes it more vulnerable to cholesteatoma, an ear disease caused by dead skin that collects in the middle ear, causing discharge and hearing loss. This can erode structures in and around the middle ear and requires surgical removal. It may be congenital or can develop as a result of repeated ear infections.

At its outer rim, the tympanic membrane is thickened and called the annulus. The malleus, the first of the three middle ear bones (Fig 1), is attached at its tip to the centre of the membrane, called the umbo (Fig 3). The handle of the malleus (Fig 3), the most identifiable mark on the tympanic membrane, lies between the fibrous and mucosal layer of the pars tensa and is attached both at the umbo and the lateral process. As the membrane is slightly concave, shining a light on it during otoscopy (examination of the external ear canal and tympanic membrane using an otoscope) reveals a triangle of light towards the front and lower aspect; this is called the light reflex and can help the viewer to orientate the membrane.

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.

**Peripheral vestibular system**
The peripheral vestibular system is responsible for maintaining balance, coordinating the position of the head and eye movement. The system consists of sacs filled with endolymph, with the fibres of the vestibulocochlear nerve distributed on the walls of these sacs. Two functionally different sensory receptor systems detect head movement:
- Semicircular canals detect rotational head movements;
- Utricles and saccules detect changes in the position of the head relating to gravity (linear acceleration) and head tilts on horizontal and vertical planes.

Hair cells moving at a different rate to the endolymph cause shearing forces, and these are detected and conducted by the vestibular nerve to the brain, which interprets the type of movement that has occurred.

**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 transmitted to the ossicles disturb the endolymph in the cochlea and cause movement of the hair-like projections on the basilar membrane. This movement of the hairs generates neural impulses, which are relayed to the brain through the cochlear nerve (Tysome and Kanegaonkar, 2018).

To guard against loud sounds, muscles attached to the malleus and stapes contract, which reduces the vibrations and protects the cochlea. This is the acoustic reflex. It takes about 40 milliseconds to occur, so if there is a sudden loud sound, such as an explosion, it will not happen in time and noise-induced hearing damage can occur.
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 auricular 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).

Table 1. Ear problems across different nursing specialties

<table>
<thead>
<tr>
<th>Specialty</th>
<th>Conditions and associated ear problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>● Diabetes 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</td>
</tr>
<tr>
<td></td>
<td>● Meningitis and brain abscess are rare, but can occur as a result of severe middle-ear infections</td>
</tr>
<tr>
<td></td>
<td>● 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)</td>
</tr>
<tr>
<td></td>
<td>● 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>
</tr>
<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>
</tr>
<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</td>
</tr>
<tr>
<td></td>
<td>● The ear is the closest structure to the temporomandibular joint, so ear pain may signal a dental problem</td>
</tr>
<tr>
<td>Immunology</td>
<td>● Patients who are immunocompromised have a higher risk of developing ear infections</td>
</tr>
<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</td>
</tr>
<tr>
<td></td>
<td>● 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</td>
</tr>
<tr>
<td></td>
<td>● Some drugs used in chemotherapy can cause irreversible damage to the hearing nerve (vestibulocochlear eighth cranial nerve)</td>
</tr>
</tbody>
</table>

In the foetus, the auditory cortex (hearing part of the brain) is fully formed, which is why newborn screening of hearing is very effective and 98.5% of babies born in the UK are tested in the first three months after birth (Public Health England, 2019).

References