Interpretation of Computed Tomography of the Petrous Temporal Bone

Abstract
This review will familiarise the reader with the normal radiological anatomy of the temporal bone as demonstrated on high-resolution computed tomography (HRCT). In addition, common pathology affecting the temporal bone will also be presented. The reader will be shown a systematic approach to viewing HRCT of the petrous temporal bone.

Keywords
Anatomy, Temporal bone, Computed Tomography, Imaging, Ear, Petrous

Introduction
High-resolution computed tomography imaging (HRCT) of the temporal bone demonstrates the bony anatomy of the external auditory canal, middle ear cleft, ossicles, labyrinth and skull base in great detail. However, HRCT lacks contrast resolution, limiting soft tissue detail. We present a systematic approach to assist in the interpretation of the normal CT anatomy of the temporal bone and highlight some common and important pathological conditions.

Anatomy and Interpretation
A systematic approach when assessing images aids interpretation and reduces the likelihood of overlooking pertinent variant anatomy and pathology. When viewing temporal bone CT, start by inspecting the lateral structures and move medially. Images should routinely be viewed in both the axial and coronal plane.

Mastoid
Variation in the pneumatisation of the petromastoid air cells is important; underpneumatisation may occur as a consequence of chronic suppurrative otitis media and cholesteatoma. The mastoid sinus contains the mastoid antrum (Latin for “cave”), which is the large central mastoid air cell present at birth. The aditus ad antrum - “entrance to the cave” (Figure 1d), connects the epitympanum with the mastoid antrum, and should be assessed for spread of disease. The Koerner septum, running posterolaterally through the air cells, is part of the petrosquamosal suture; it acts as a barrier to the extension of infection between the lateral and medial mastoid air cells and also serves as an important surgical landmark.

External Ear
The external ear consists of the pinna and the external auditory canal (EAC). The S-shaped EAC, which is located postero-inferior to the temporo-mandibular joint, measures approximately 2.5cm in length. The lateral 1/3 of the canal is made of fibrocartilage whilst the tympanic bone forms the medial 2/3. The isthmus is the narrowest point and lies at the bony-cartilagenous junction (mean diameter of 6mm). The external auditory canal redirects and redistributes sound from the conchal bowl to the tympanic membrane and optimises the presentation of certain frequencies. The EAC can be visualised on axial, coronal or sagittal

Pathology Checklist
- Acute mastoiditis with or without abscess
- Coalescent mastoiditis

E K Hughes 1
J P Hughes 2
G Madani 1

1 Department of Imaging, Imperial College Healthcare NHS Trust, London
2 Head and Neck Unit, University College Hospital, London

Correspondence:
E. K. Hughes
Department of Imaging, Imperial College Healthcare NHS Trust, London, W6 8RF
Interpretation of Computed Tomography of the Petrous Temporal Bone

Figure 1: Consecutive axial CT images through the right temporal bone demonstrating normal anatomy from cephalic to caudal.
Interpretation of Computed Tomography of the Petrous Temporal Bone

images. Multiplanar reconstruction aids the diagnosis of bony erosion, e.g. cholesteatoma (Figure 3), necrotising otitis externa (Figure 6), squamous cell carcinoma (Figure 6) and stenosis (Figure 7 - exostoses, osteoma). In health, the thin tympanic membrane which separates the medial end of the EAC from the middle ear cavity, may not be completely visualised on CT. 3

Middle Ear

The middle ear cleft can be divided into three compartments. Viewed in the coronal plane, a line drawn from the lower edge of the scutum to the tympanic segment of the facial nerve divides the superior compartment, the epitympanum, from the mesotympanum (tympanic cavity proper). The hypotympanum, the inferior compartment, lies below a parallel line drawn to the floor of the EAC.

The Ossicles

The ossicles should be evaluated in the axial and coronal planes. The malleus is the most anterior ossicle. Its head articulates with the body of the incus at the malleo-incudal joint (Figure 1e). The neck lies inferior to the head. The handle and lateral process of the malleus (not well seen on axial CT) are embedded in the tympanic membrane. In addition to its body, the incus has a short process, which is orientated posteroslateral and is located in the fossa incudis. The long process of incus, passes inferomedially and forms a right angle with the small lenticular process which articulates with the stapes capitulum (Figure 1h). The incus transmits sound energy from the malleus to the stapes. The stapes, with its anterior and posterior crura, articulates via its footplate at the oval window. The footplate transmits sound energy through the oval window (Figure 1f, g).

- Exostoses
- Osteoma
- Keratosis obturans
- Necrotising otitis externa
- Medial canal fibrosis
- Cholesteatoma
- Squamous cell carcinoma

Pathology Checklist

Windows

The stapes footplate lies on the oval window and transmits sound energy to the vestibule and subsequently to the cochlea (Figure 1f, g). Thickening of the footplate is seen in pericochlear otosclerosis (Figure 4a) and is best appreciated on axial imaging. The anatomy of the oval window recess is best assessed on coronal imaging. The recess may be overhung by the tympanic facial canal (Figure 2c).
The round window lies at the posterolateral aspect of the basal turn of the cochlea and allows dissipation of sound energy which has travelled through the cochlea (Figures 1i, 2d). The round window niche is the small fossa on the medial aspect of the middle ear cleft leading to the round window. In a normal subject the niche should be aerated.

**Epitympanum**

The tegmen tympani is a thin bony plate that separates the epitympanum from the dura of the middle cranial fossa. It acts as a barrier between the middle ear and intracranial cavity. The integrity of the tegmen tympani is best evaluated on coronal images (Figure 2a), although HRCT may overestimate tegmen dehiscence. A low lying tegmen tympanum is a normal variant which is a potential surgical hazard.

Prussak’s space (Figure 2a) represents the lateral epitympanic recess and is a classic location for pars flaccida cholesteatoma

**Mesotympanum**

In addition to part of the ossicular chain, the mesotympanum also contains two muscles, tensor tympani (innervated by the trigeminal nerve) and stapedius (innervated by the facial nerve). The tensor tympani arises in a bony channel medial to the Eustachian tube and passes superiorly. At the processus choleaformis, on the medial wall of the epitympanum, the muscle

---

**Pathology Checklist**

- Otitis media
- Acquired cholesteatoma
- Congenital cholesteatoma
- Glomus tympanicum

---

**Figure 3**: Cholesteatoma. (a). Axial CT image demonstrates soft tissue attenuation within the right middle ear cavity, which has resulted in erosion of the long process of the incus (black arrow). Note, the normal left long process (white arrow). (b). Coronal CT of same patient further demonstrates erosion of the long process of the incus (long arrow). In addition, the soft tissue abuts the facial canal. There is “blunting” of the scutum (short arrow) [compare with the left]. (c). Coronal CT images of another patient, shows bony dehiscence of the left tegmen (black arrow.)

**Figure 4**: Cholesteatoma. (a). Axial CT image demonstrating a spongiotic focus at the anterior margin of the oval window (long black arrow) in the fissula ante fenestrum diagnostic of fenestral otosclerosis. In addition, there is thickening of the stapes footplate indicating oval window involvement (b). Coronal CT shows thickening of the stapes footplate. Note the narrow oval window recess (black arrow), making surgical approach challenging. (c) Axial CT image of another patient illustrates pericochlear lucency (arrow) indicative of pericochlear otosclerosis.
turns 90° to insert onto the neck of the malleus. Stapedius arises from the pyramidal eminence (Figure 1g) and inserts onto the posterior margin of the stapes.

The posterior wall structures are best appreciated on axial imaging. The pyramidal eminence separates the facial recess, located laterally, from the medially located sinus tympani (Figure 1g). The descending, or mastoid, facial canal lies immediately deep to the facial recess. The posterior genu, at the junction of the tympanic and descending portion, is a common site for bony dehiscence of the facial canal. The sinus tympani, is a surgical blind spot where cholesteatomas may be overlooked.

The medial wall of the mesotympanum contains a rounded prominence, the cochlear promontory, formed by the bone overlying the basal turn of the cochlea (Figure 1j). It is appreciated on axial and coronal imaging, and lies between the oval window superiorly and the round window niche posteroinferiorly. The promontory is the classic site of erosion by glomus tympanicum.

**Hypotympanum**

The hypotympanum is a shallow trough on the floor of the middle ear cavity, which is separated from the jugular bulb by a thin plate of bone.

**Inner Ear**

The inner ear comprises the bony labyrinth (otic capsule) and membranous labyrinth (the fluid-filled spaces within the bony labyrinth). The bony labyrinth, which is well demonstrated on CT, consists of the cochlea, the vestibule, the semicircular canals and the cochlear and vestibular aqueducts. The cochlea is a canal, which encircles a central bony axis (the modiolus) 2.5 times. The modiolus (Figure 1g) contains the spiral ganglion, the cell bodies of the cochlear nerve, which enter the cochlea from the internal auditory canal. A fine osseous spiral lamina projects from the modiolus and divides the bony canal into three spiral chambers: the scala tympani (posterior), scala vestibuli (anterior) and the scala media, which contains the organ of Corti. The base of the cochlea lies at the lateral end of the internal auditory canal and the basal turn opens into the round window niche.

The vestibule (Figures 1c, 2c), which is separated laterally from middle ear by the oval window, is the largest component of the membranous labyrinth and consists of the utricle and saccule (not seen on imaging). The semicircular canals arise from the superior, lateral and posterior aspects of the vestibule. The crus communis (or common crus) is the common origin of the posterior and superior canals. The arcuate eminence is an elevation of the roof of the petrous pyramid; although believed to form the roof of the superior semicircular canal and traditionally used as a landmark in a middle cranial fossa approach to the internal auditory canal, its relationship with the superior canal is inconsistent. The plane of the posterior SCC is parallel to the petrous ridge. The bone overlying the lateral semicircular canal forms the medial wall of the
Interpretation of Computed Tomography of the Petrous Temporal Bone

epitympanum; this is a characteristic site of bony erosion by large cholesteatoma resulting in a labyrinthine fistula.7

The cochlear aqueduct contains the perilymphatic duct and passes in the transverse plane inferior to the internal auditory canal (Figure 1j). Laterally the cochlear aqueduct communicates with the scala tympani of the basal turn of the cochlea. Medially it has a funnel shaped opening into the subarachnoid space of the posterior fossa, superomedial to the jugular foramen.1 The vestibular aqueduct (Figures 1b, c) contains the endolymphatic duct and sac and arises from the posteromedial aspect of the vestibule and travels parallel to the posterior semicircular canal to open at the posterior aspect of the petrous ridge (Figure 1c).

<table>
<thead>
<tr>
<th>Pathology Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Semicircular canal dehiscence</td>
</tr>
<tr>
<td>· Labyrinthitis ossificans</td>
</tr>
<tr>
<td>· Large vestibular aqueduct</td>
</tr>
<tr>
<td>· Otosclerosis</td>
</tr>
</tbody>
</table>

**Vessels, foramina and canals**

The internal auditory canal transmits the facial and vestibulocochlear nerves from the cerebellopontine cistern. The intracanalicular nerves are not seen on CT; only gross pathology which results in bony erosion or expansion is appreciated. The posteriorly positioned vestibulocochlear nerve divides into the cochlear nerve (not seen on CT), the superior vestibular nerve, which passes through its own canal, and the inferior cochlear nerve (Figure 1f).

In the internal auditory canal, the facial nerve travels anteriorly, then passes into the short labyrinthine canal curving anteriorly and medially above the cochlea (Figure 1d). The geniculate ganglion lies anterior to the junction of the labyrinthine and tympanic canal; the nerve forms an acute angle here. The greater petrosal nerve (not seen) passes anteriorly and the tympanic (horizontal) segment (Figure 1e) passes posteriorly along the medial wall of the middle ear passing below the lateral semicircular canal and superolateral to the oval window recess. The tympanic segment of the facial nerve is at risk of erosion from middle ear cholesteatoma. At the posterior genu the facial canal turns inferiorly; this is a common site of bony dehiscence. The mastoid, or descending segment, (Figure 2e) of the canal is the longest portion. It passes vertically down to the stylomastoid foramen through the mastoid portion of the temporal bone.

Nerve sheath tumours may occur anywhere along the course of the facial nerve but haemangioma of the facial nerve characteristically occurs at the anterior genu and results in a reticular or honeycomb abnormality.8

**Vessels**

The internal carotid artery enters the skull base in the carotid canal travelling a short distance vertically. The canal then has a 90° bend forming the horizontal petrous canal (Figure 1k, Figure 9) which is closely related to the medial wall of the middle ear (separated from the tensor tympani muscle by the Eustachian canal). An aberrant carotid artery passes through the middle ear cleft as a vascular middle ear mass.

The jugular vein is the continuation of the sigmoid sinus starting in the jugular foramen (Figure 1k). At its origin, the vein expands to form the jugular bulb. The smooth pars vascularis occupies the posterolateral portion of the jugular bulb and transmits the vagus and spinal accessory nerves. The irregular

**Figure 7: EAC exostoses versus EAC osteoma.** (a) Axial CT image reveals bilateral EAC narrowing secondary to circumferential benign bony sessile overgrowth. The condition develops in response to chronic cold water exposure and has a 70% prevalence in surfers. 4t is bilateral, sessile and arises in the medial EAC, in contrast to EAC osteoma (b), which is unilateral, arises from the lateral canal and characterised by a focal osseous protuberance (arrow).
Interpretation of Computed Tomography of the Petrous Temporal Bone

A high jugular bulb lies above the level of the round window niche. A dehiscent high-riding jugular bulb may herniate into the hypotympanum presenting a surgical hazard. Dehiscence of the jugular bulb into the round window niche or posterior semicircular canal is associated with hearing loss.9

Other Canals
The petromastoid canal passes from the mastoid antrum to the posterior fossa, at the level of the superior semicircular canal. The canal is a vestige of the neonatal subarcute fossa, transmitting the subarcuate vessels. It is a potential site for an extra-labyrinthine fistulae.10

The inferior tympanic canaliculus, extends from the jugular foramen to the medial wall of the middle ear and transmits the inferior tympanic branch of the glossopharyngeal nerve (Jacobson’s nerve). The mastoid canaliculus extends from the posterolateral aspect of the jugular foramen to the descending facial nerve canal and contains the auricular branch of the vagus nerve (Arnold’s nerve). Both of these canals are important surgical landmarks for the identification of the cranial nerves in the jugular fossa. Enlargement of either canaliculi is an early sign of glomus jugulotympanicum.10

Petrous Apex
The petrous apex is the anterior portion of the temporal bone lying anteromedial to the bony labyrinth. Asymmetric pneumatization of the petrous apex may be mistaken for pathology. Pathology in the petrous apex results in expansion and/or bony erosion.

Conclusion
High resolution CT of the temporal bone is a commonly requested radiological investigation in patients presenting to the otology clinic. This review illustrates the salient normal anatomy with examples of common or important pathologies.

Conflict of Interest
All authors have no conflict of interest to declare. No extraneous funding was obtained.
Interpretation of Computed Tomography of the Petrous Temporal Bone

References