

# The petrous apex: A guide for the general radiologist

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## Introduction

Detailed imaging of the skull base can be a daunting prospect for non-specialist head and neck radiographers and radiologists. Fortunately, the petrous apex (the most anteromedial part of the temporal bone) is easily identified on CT and MRI. Despite the fact that petrous apical pathology may give rise to a range of clinical signs and symptoms (secondary to mass effect on local neurovascular structures),<sup>1</sup> the list of disorders is relatively small. These diseases and petrous apex anatomy will be described below.

## Imaging strategies

CT imaging, best for bony detail, requires 3D volume thin (sub-millimetre) section acquisitions with high spatial frequency reconstructions. MRI, with its inherent wide range of soft tissue signals, uses standard spin echo T1 and T2-weighted sequences and may also benefit from high resolution 3D imaging sequences such as CISS (Constructive Interference in Steady State, Siemens), BTFE (Balanced Turbo Field Echo, Philips) and FIESTA (Fast Imaging Employing STEADY-state Acquisition, GE). The latter three utilise *balanced* gradients along all three axes, meaning that fluids such as cerebrospinal fluid (CSF) appear bright. There is also a role for fat suppression techniques, intravenous gadolinium-based contrast agents and non-echo planar diffusion-weighted imaging.

## Anatomy and contents of the petrous apex

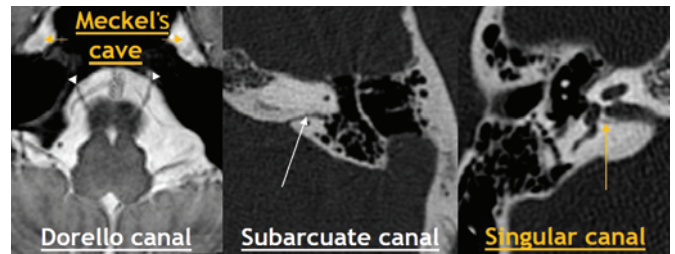
The petrous bone is one of five parts of the temporal bone, which also consists of squamous (bony temple and zygomatic arch), mastoid (post-auricular) and tympanic (surrounding external auditory canal) portions, as well as the styloid process. The word petrous derives from the Latin word *petrosus* meaning rock-like or hard.

Petrous bones are now much sought after in the field of paleogenomics due to their high internal rates of DNA preservation – four to 16 times that of teeth and over 100-fold greater than other bones.<sup>2</sup>

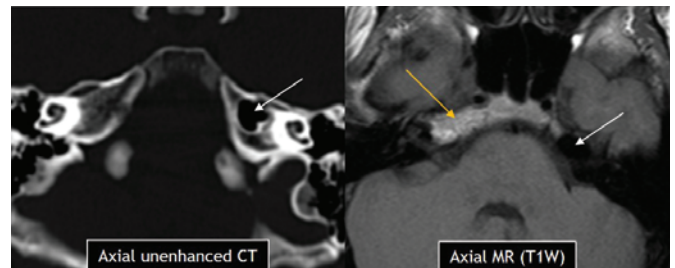
The petrous apex is the medial-most part of the temporal bone and has the following boundaries:<sup>3</sup>

- Medial – petro-occipital fissure;
- Lateral – inner ear structures;
- Anterior – petro-sphenoidal fissure, internal carotid artery;
- Posterior – posterior cranial fossa;
- Superior – middle cranial fossa, Meckel's cave, internal carotid artery;
- Inferior – jugular bulb, inferior petrosal sinus.

The internal auditory canal divides the petrous apex in two: the anterior bony aspect usually comprises normal bone marrow and the smaller posterior part contains the otic capsule (cochlear and semicircular canals).



**Figure 1**



**Figure 2**

Several neural/vascular channels intimately related to the petrous apex are identifiable at CT/MR imaging<sup>4</sup> (**figure 1**):

- Meckel's cave contains the trigeminal ganglion;
- Dorello's canal transmits the abducens nerve [VI] (arrow-heads);
- Subarcuate canal contains the subarcuate artery – supplies labyrinth, facial canal, mastoid;
- Singular canal contains the singular nerve – innervates posterior semicircular canal.

## Normal variations of anatomy commonly mistaken for pathology

*Asymmetric pneumatization* is apparent in ~4–7% of patients<sup>5</sup> and either side may be incorrectly described as abnormal at MR.<sup>4</sup> On CT (**figure 2**), the pneumatized side contains air cells (white arrow) without expansion and the non-pneumatized side normal bone marrow. MR demonstrates T1 and T2 signal voids within the pneumatized petrous apex (white arrow). The non-pneumatized petrous apex has high T1 and high T2 signal (yellow arrow) due to normal marrow fat, with signal suppression observed on fat-saturated sequences.

A *petrous apex effusion* describes simple fluid trapped within a pneumatized petrous apex, without clinical evidence of infection.<sup>5</sup> A prior CT (if available) may demonstrate petrous apex pneumatization. MR will demonstrate low T1 signal and high T2 signal (consistent with fluid) within the pneumatized petrous apex. Trapped fluid gives non-enhancing, non-expanded opacified petrous apex air cells at CT.

## Developmental lesions

### Meningocele

Meningoceles are rare “don't touch” lesions often discovered incidentally at imaging.<sup>1</sup> They are focal protrusions of dura mater into the petrous apex, usually from Meckel's cave.<sup>4</sup> Petrous apex meningoceles are more common in women and may be bilateral, believed to result from raised intracranial pressure transmitted through Meckel's cave.<sup>4</sup> They have also been reported following surgery at the petrous apex.<sup>1</sup>

CT shows smooth lobulated expansion of the petrous apex

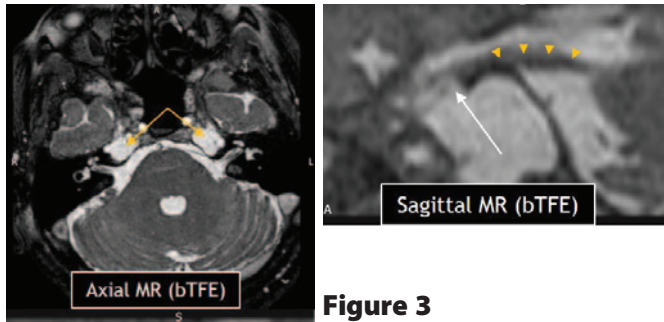


Figure 3

and MR reveals a corresponding non-enhancing cystic lesion following CSF signal on all sequences. Sagittal images (figure 3) may demonstrate the cisternal segment of the trigeminal [V] nerve (arrow-heads) and the point of communication with Meckel's cave (white arrow), confirming the correct diagnosis of a meningocele.

**Inflammatory lesions**

**Cholesterol granuloma**

Also known as *cholesterol cysts*, cholesterol granulomas are the most common primary petrous apex lesion,<sup>4</sup> but actually occur more commonly in the mastoid segment or middle ear.<sup>1</sup> They are thought to develop from an obstructed air cell (eg within a pneumatised petrous apex), the end result manifesting as trapped blood breakdown products with surrounding inflammation/infection.<sup>5</sup> Local mass effect results in various symptoms but patients most often present with hearing loss preceding headache and vertigo.<sup>1</sup>

MR imaging most reliably diagnoses a cholesterol granuloma,<sup>4</sup> showing a well-defined homogeneous hyperintense lesion on T1, T2 and fat-suppressed T1-weighted sequences (figure 4). Blood breakdown products and/or cholesterol crystals account for the high T1 signal.

**Cholesteatoma**

Cholesteatomas are congenital or acquired lesions representing 4–9% of all petrous apex lesions.<sup>4</sup> Congenital cholesteatomas are synonymous with *epidermoid cysts* and arise from abnormally located ectodermal epithelial rests.<sup>5</sup> They are much more common at the petrous apex than acquired cholesteatomas,<sup>4</sup> which usually occur within the tympano-mastoid region in association with tympanic membrane perforation/retraction.

CT (figure 5) displays an expansile mass anteriorly within the tympanic cavity (arrow) eroding the head of malleus, tegmen tympani and apical turn of the cochlea, and MR demonstrates a corresponding non-enhancing mass with restricted diffusion.

**Mucocoele**

A mucocoele is an obstructed air cell lined by respiratory epithelium capable of secreting mucous with the accumulated mucoid material causing bone remodelling and a local inflammatory response.<sup>1</sup> A primary petrous apex mucocoele is extremely rare but may cause localised pain and/or cranial nerve palsies.<sup>5</sup>

Mucocoeles, cholesteatomas and cholesterol granulomas all have overlapping imaging features. Table 1 is a useful adjunct to help distinguish each at MR.

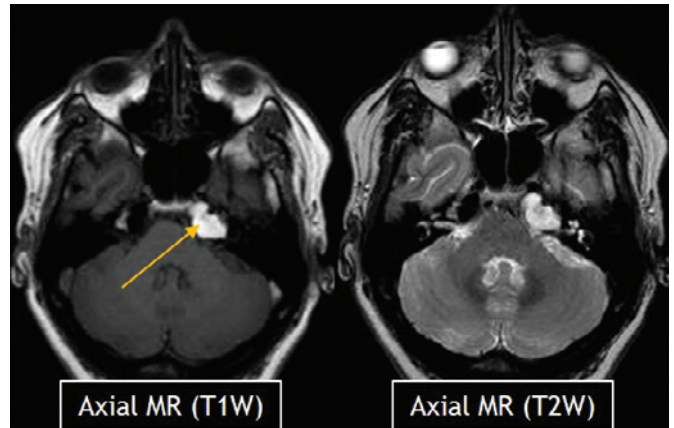


Figure 4

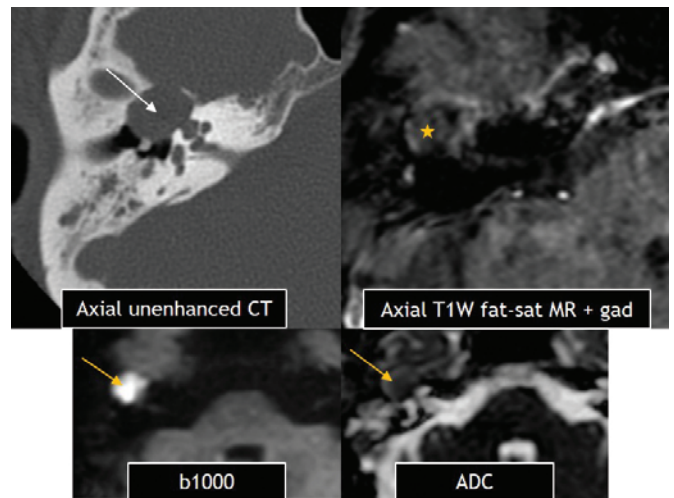


Figure 5

**Petrous apicitis**

Petrous apicitis occurs when infective oto-mastoiditis extends medially into a pneumatised petrous apex.<sup>5</sup> An abscess may also develop if drainage of the petrous apex to the middle ear is obstructed.<sup>4</sup> Patients present with pyrexia and some (or all) symptoms of *Gradenigo syndrome*:<sup>4</sup> ear pain, abducens [VI] nerve palsy and facial pain in the distribution of the trigeminal [V] nerve.

MR (figure 6) demonstrates high T2 (white arrow) and low T1 petrous apex signal and associated abscess formation manifests as rim enhancement (arrow-heads) and restricted diffusion. In this case, the left internal carotid artery is also occluded. Other potential complications include meningitis, dural sinus thrombosis and cerebral abscess.<sup>1</sup>

**Benign tumours**

**Meningioma**

At CT, meningiomas are hyper-attenuating dural-based masses and often demonstrate low T1 and low T2 signal on MR. They enhance avidly and can cause hyperostosis of the petrous apex.<sup>1</sup>

*Petroclival* meningiomas extend from the medial petrous

	Mucocoele	Cholesterol granuloma	Cholesteatoma
T1	↓ or → (if proteinaceous)	↑ (met-haemoglobin)	→ or ↓
T2	↑	↑ (met-haemoglobin)	↑
Enhancement	peripheral mucosal	nil	nil
DWI	no restriction	no restriction*	restriction

\*Cholesterol granulomas may occasionally restrict diffusion due to the presence of blood breakdown products.

Table 1



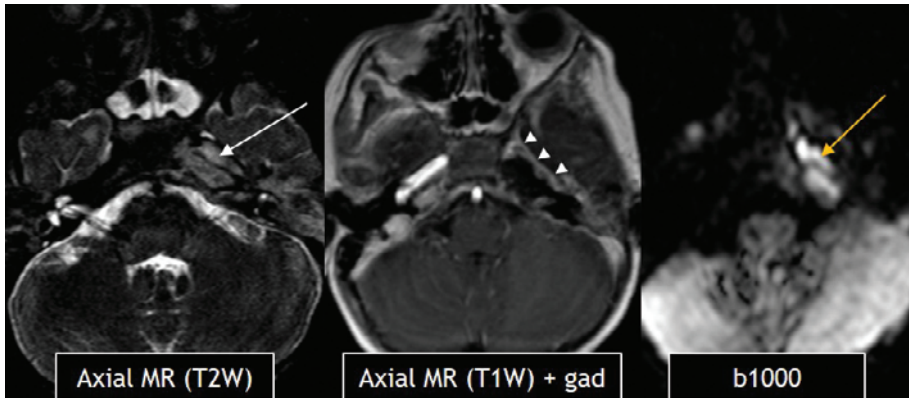


Figure 6

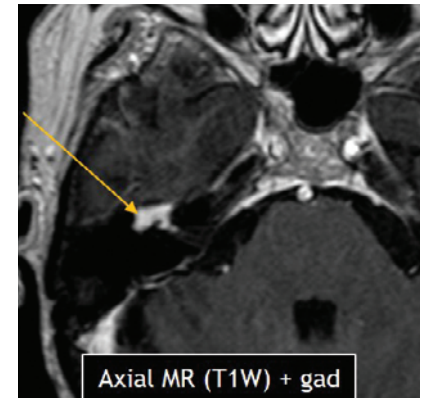


Figure 7

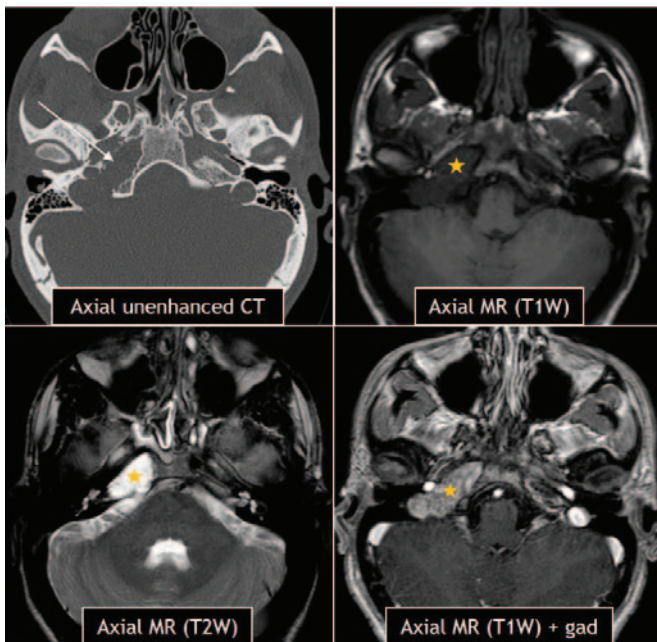


Figure 8

apex and may enter Meckel's cave and Dorello's canal.<sup>5</sup> *Cerebellopontine angle* meningiomas can enter the internal auditory canal.<sup>4</sup>

**Schwannoma**

Petrous apex schwannomas typically originate from cranial nerves V, VII or VIII and are usually iso-dense to the brain at CT.<sup>4</sup> They usually appear as smooth expansile low T1 and high T2 signal enhancing lesions at MR.<sup>5</sup>

*Trigeminal* [V] schwannomas may arise from the cisternal segment or within Meckel's cave and *vestibular* [VIII] schwannomas often fill the internal auditory canal, sometimes enlarging the porus acusticus.<sup>4</sup> *Facial* [VII] schwannomas are rare but usually originate from the geniculate ganglion, extend proximally or distally and expand the facial canal<sup>4</sup> (figure 7).

**Malignant tumours**

**Chondrosarcoma**

Chondrosarcomas are malignant cartilaginous tumours thought to occur within remnants of cartilage along skull base synchondroses.<sup>1</sup> They therefore originate from the petro-clival and petrosphenoidal junctions when involving the petrous apex.<sup>4</sup> There are associations with *Ollier disease*, *Maffucci syndrome* and *Paget disease*.<sup>4</sup>

CT (figure 8) demonstrates an expansile petrous apertic lesion (arrow) with corresponding mild T1 and characteristic T2 signal hyperintensity at MRI (star). The presence of enhancement helps to distinguish from other lesions (eg

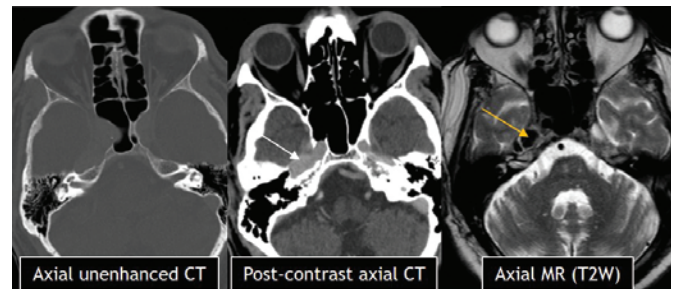


Figure 9

mucocoeles). Sometimes rings and arcs of matrix calcification may be seen, reflecting the chondroid nature of this lesion.<sup>5</sup>

**Bony metastasis**

Temporal bone metastases most commonly affect the petrous portion.<sup>4</sup> Malignancies frequently metastasising to the petrous apex include breast, lung, prostate and renal cell carcinomas.<sup>5</sup>

**Vascular lesions**

**Petrous carotid aneurysm**

Aneurysms of the petrous internal carotid artery are rare, with most discovered incidentally.<sup>5</sup> They can be surprisingly large when first encountered but may cause tinnitus, cranial nerve palsies or Horner syndrome.<sup>1</sup>

CT (figure 9) demonstrates an expanded carotid canal in the anterior petrous apex, with an enlarged internal carotid artery seen post-contrast administration (arrow). MRI shows a corresponding large luminal flow void, which may be layered or have a "swirling" appearance due to turbulent flow.<sup>1</sup>

**Osseous dysplasias**

CT is the best modality for assessing osseous dysplasias. Those that involve the petrous apex also tend to affect much of the skull base.

*Fibrous dysplasia*: bony expansion with preservation of the cortex and extensive characteristic ground-glass internal matrix.<sup>4</sup>

*Paget disease*: widening of the diploic space, over-riding enlarged frontal bone and a diffuse "cotton wool" appearance.<sup>5</sup>

**Summary**

Having discussed normal anatomy, highlighted normal anatomical variations and presented a variety of common and important petrous apex lesions, we hope that the reader can now evaluate this complex anatomical location with greater confidence.

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