Computed tomography is one of a number of imaging modalities that can usefully be employed to investigate ear disease

Diagnostic imaging of ear disease in the dog and cat

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MOST dogs and cats with common aural conditions, such as otitis externa or aural haematoma, may be treated satisfactorily without the need for diagnostic imaging. However, animals with recurrent or severe otitis, and those with more marked signs, such as para-aural swelling, pain on opening the mouth, vestibular syndrome or facial paralysis, may benefit from a more thorough work-up to examine the middle ear and adjacent structures. In such cases, the anatomical complexity and relative inaccessibility of these structures is best addressed by diagnostic imaging – involving, as appropriate, radiography, computed tomography, magnetic resonance imaging or ultrasonography. This article reviews the use of these imaging techniques in dogs and cats with clinical signs of ear disease and illustrates some of the more typical findings.

ANATOMY OF THE EAR

The ear may be divided into three parts: external, middle and inner. The external ear includes the pinna and the external auditory canal and is usually examined by direct inspection rather than diagnostic imaging. The tympanic membrane separates the external auditory canal from the middle ear. Both the middle and inner ear are contained in the petrous temporal bone. The middle ear comprises an air-filled tympanic cavity containing the three auditory ossicles (malleus, incus and stapes), and is connected to the nasopharynx via the auditory (Eustachian) tube.

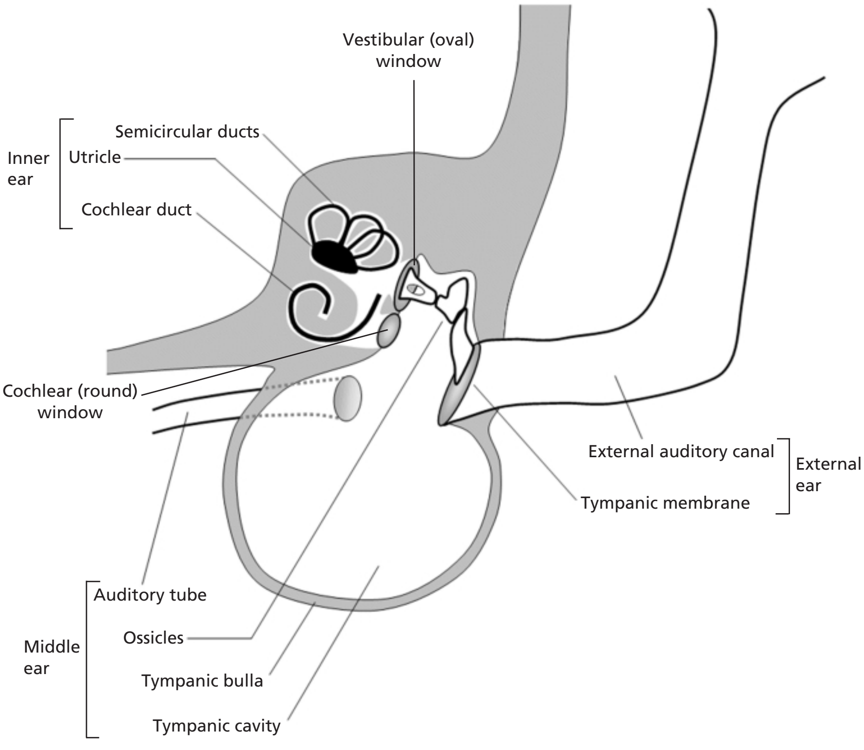
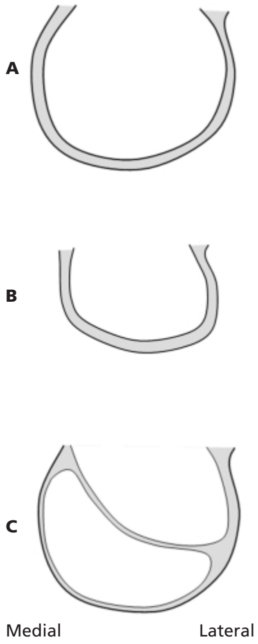


Diagram showing the external, middle and inner ears of the dog. The external ear canal and tympanic cavity are normally air-filled, while the cavities of the inner ear (in black) are normally fluid-filled



Variations in the conformation of the tympanic bulla. (A) In many canine breeds, the tympanic bulla is relatively large and rounded. (B) In some breeds (eg, Cavalier King Charles spaniel), it is smaller and flatter. (C) The feline bulla has a thin wall and is incompletely divided by a bony septum into two compartments (ventromedial and dorsolateral)

In dogs, the tympanic cavity is usually quite large and rounded, although in some breeds (eg, Cavalier King Charles spaniel, bulldog) it is smaller and flatter. Not all dogs' ears are symmetrical and one bulla may be larger than the other for no apparent reason. The feline tympanic bulla is divided into two compartments (ventromedial and dorsolateral) by an incomplete bony septum.

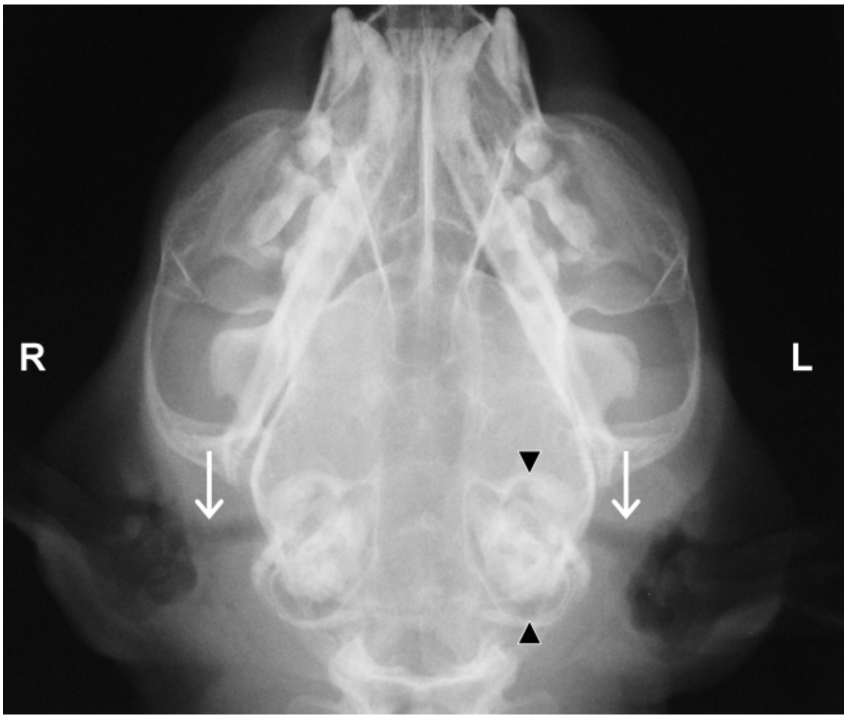
The inner ear is separated from the middle ear by two membranous structures: the vestibular (oval) window, where the stapes articulates, and the cochlear (round) window, which acts as a damper for sound waves. The inner ear is composed of fluid-filled labyrinths: the membranous labyrinth (semicircular ducts, utricle and cochlear duct) contains endolymph; the bony labyrinth surrounds the membranous labyrinth and contains perilymph. Perilymph and endolymph have different chemical compositions and therefore do not normally communicate.

Indications for diagnostic imaging of the ear

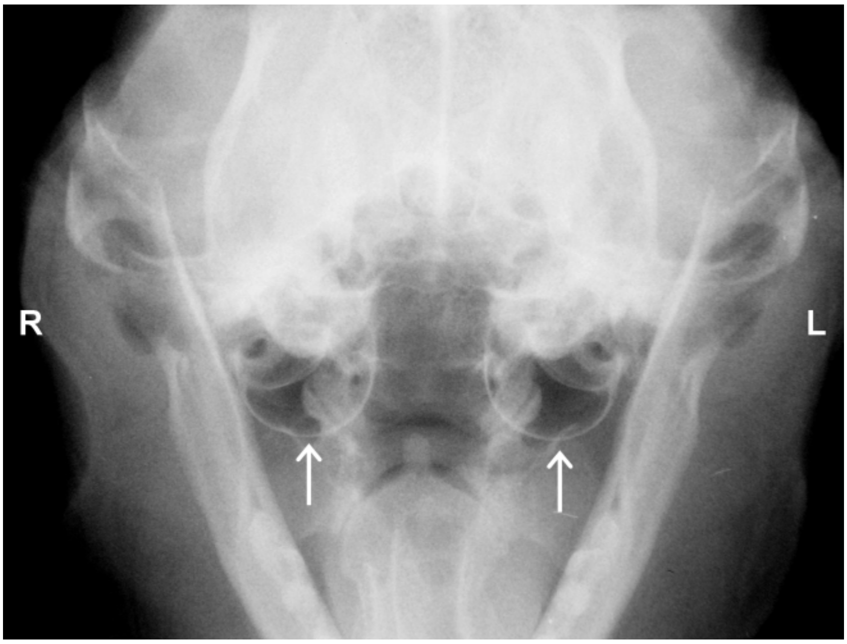
- Recurrent or severe otitis (suspected otitis media)
- Para-aural swelling or mass
- Fistulous tract
- Trauma
- Inability to open, or pain on opening, the mouth
- Neurological dysfunction
  - Vestibular syndrome (ataxia, loss of balance, head tilt, nystagmus)
  - Facial paralysis
  - Horner's syndrome
  - Hearing deficit
  - Hemifacial spasm (inflammation of the facial nerve secondary to otitis)
- Nasopharyngeal polyp
- Complications following surgery (eg, total ear canal ablation)

Radiography

Of the various radiographic projections that may be employed to examine the head, the dorsoventral (or ventrodorsal) and rostrocaudal (open-mouth) views are generally the most useful because they enable comparisons between the left- and right-hand sides, which can aid recognition of abnormalities. In each of these views, the tympanic bullae are superimposed on other parts of the skull, which complicates interpretation. An additional projection that minimises superimposition is the left (or right) 20° ventral-right (or -left) dorsal oblique view.

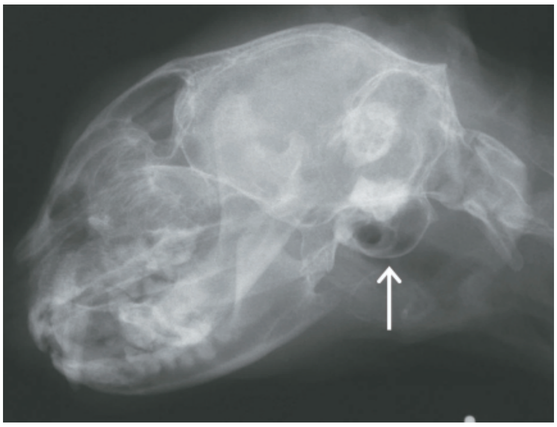


Normal ventrodorsal radiograph of the head of a cat. The air-filled external ear canals are visible as lucent structures (arrows) within the soft tissue lateral to the petrous temporal bone. The middle ear (arrowheads) is superimposed on the skull and cannot be adequately assessed in this view



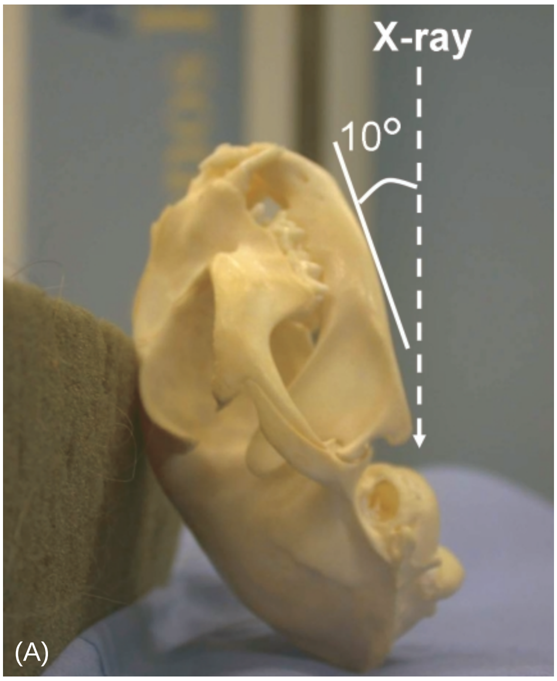
Normal rostrocaudal (open-mouth) radiograph of the head of a cat. The tympanic cavities (arrows) are air-filled and rounded, with well-defined thin walls. A bony septum is visible dividing each tympanic cavity into ventromedial and dorsolateral compartments

(left) Cat positioned for a left 20° ventral-right dorsal oblique view of the right bulla. The neck is extended and the wedge under the chin supports the skull in a rotated position. In long-eared dogs, it is important to pull the pinnae dorsally to avoid superimposition of the external ear canal on the middle ear.
(right) The resulting radiograph shows the right bulla (arrow) projected ventral to the skull. The contralateral oblique view should always be acquired for comparison and completeness

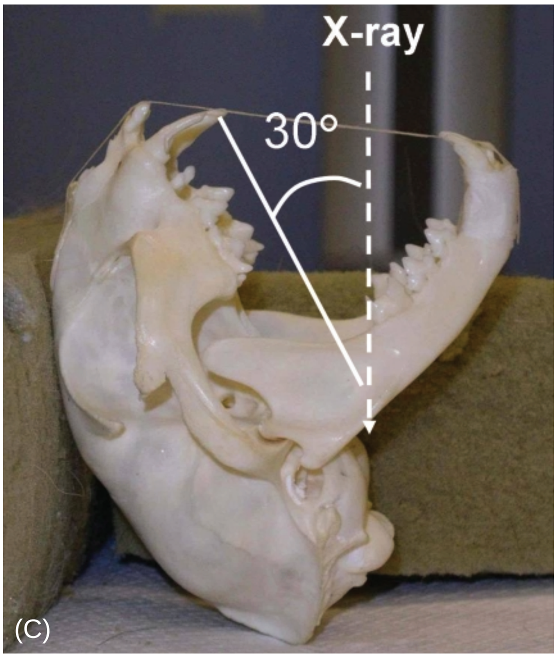


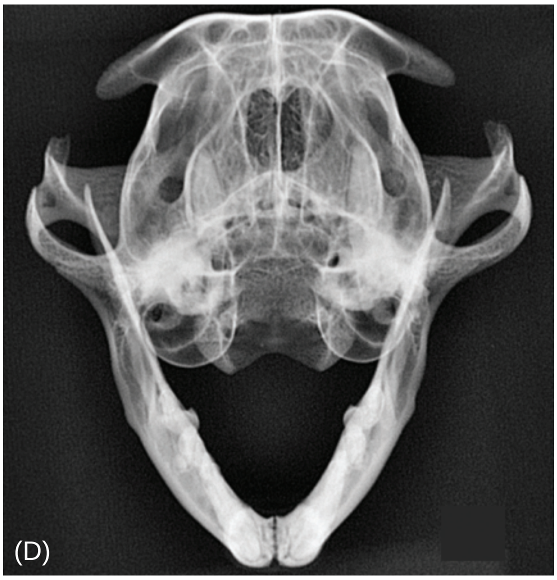
In cats, the rostro-10° ventral-caudodorsal (closed-mouth) projection is an alternative to the rostrocaudal (open-mouth) view. Both projections enable good visualisation of the tympanic bullae, but some clinicians find the closed-mouth view easier to acquire. It is also a useful alternative in an animal that cannot open its mouth.

The skull is a difficult region to assess because of its complexity and the superimposition of structures in radiographs. Poor positioning, including obliquity, can make interpretation more difficult. General anaesthesia



Alternative projections for the feline tympanic bullae are illustrated by a feline skull positioned for rostro-10° ventral-caudodorsal (closed-mouth) (A) and rostrocaudal (open-mouth) (C) projections. The open-mouth view is effectively a rostro-30° ventral-caudodorsal view, the reference being the hard palate. Both radiographs obtained with these two projections (B and D, respectively) allow good visualisation of the tympanic bullae and simultaneous comparison of the left- and right-hand sides. The bullae are partly superimposed on the occipital condyles in both views





is recommended for radiography of the head, and the use of foam wedges and ties aids correct positioning. Radiographs should be repeated until good positioning is achieved. Diagnosis of disease should not be made on the basis of a subtle finding observed on a radiograph from a malpositioned animal.

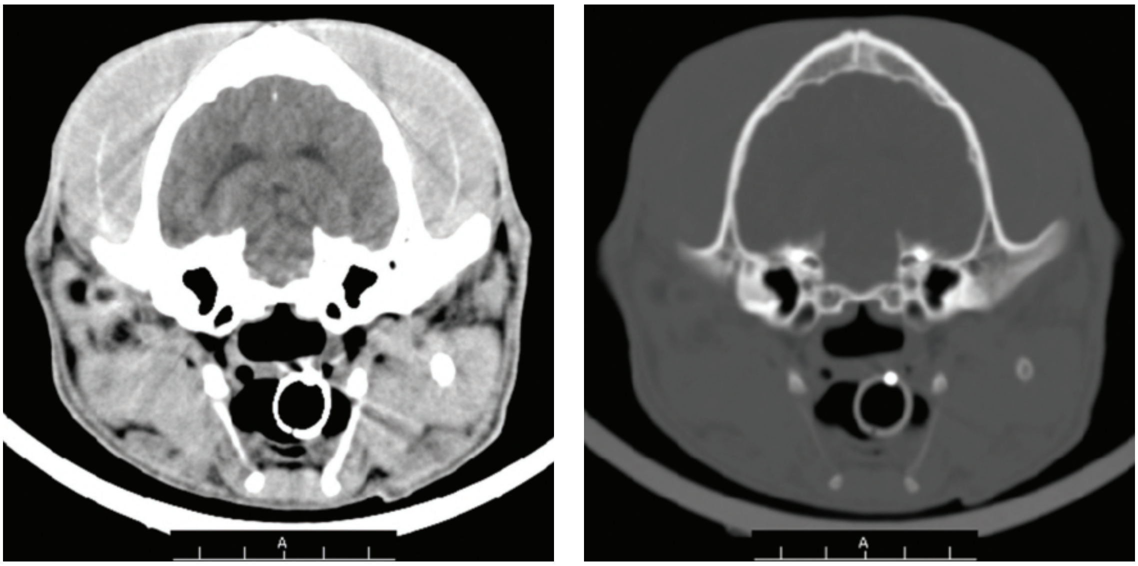
Computed tomography

Computed tomography (CT) is based on the same physical principles as radiography and produces images that resemble radiographs of sections of the body. A major advantage of cross-sectional images is the ability to examine structures without the confusing effect of superimposition. CT images of the ears are usually acquired in the transverse plane using thin contiguous slices (1·5 mm) and a high resolution reconstruction algorithm. Patients are normally placed in sternal recumbency, with the head supported in a padded trough to facilitate stable and symmetrical positioning. Patients undergoing CT of the head are either sedated or anaesthetised. The scanning time is usually about one minute.

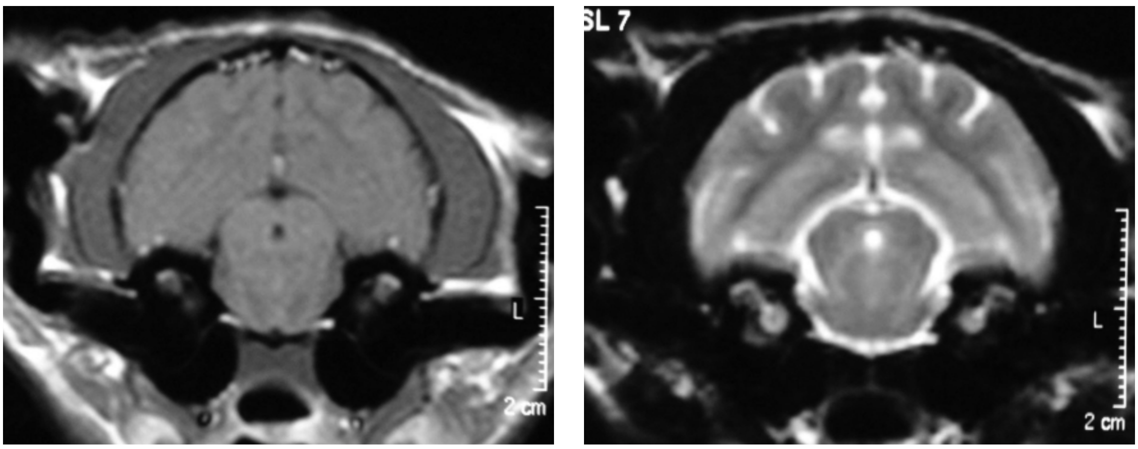
CT enables a relatively detailed examination of the ears and adjacent structures. As in conventional radiographs, air and bone can be readily distinguished, and this makes CT an excellent choice for imaging the middle ear. If abnormalities are suspected in other structures, such as the brain, a second CT scan with settings more appropriate for the brain can be acquired. A repeat CT scan following intravenous administration of organic iodide contrast medium may aid the detection of lesions affecting soft tissues because the contrast medium tends to accumulate in vascular structures and, if the blood–brain barrier is damaged, in the brain.

Magnetic resonance imaging

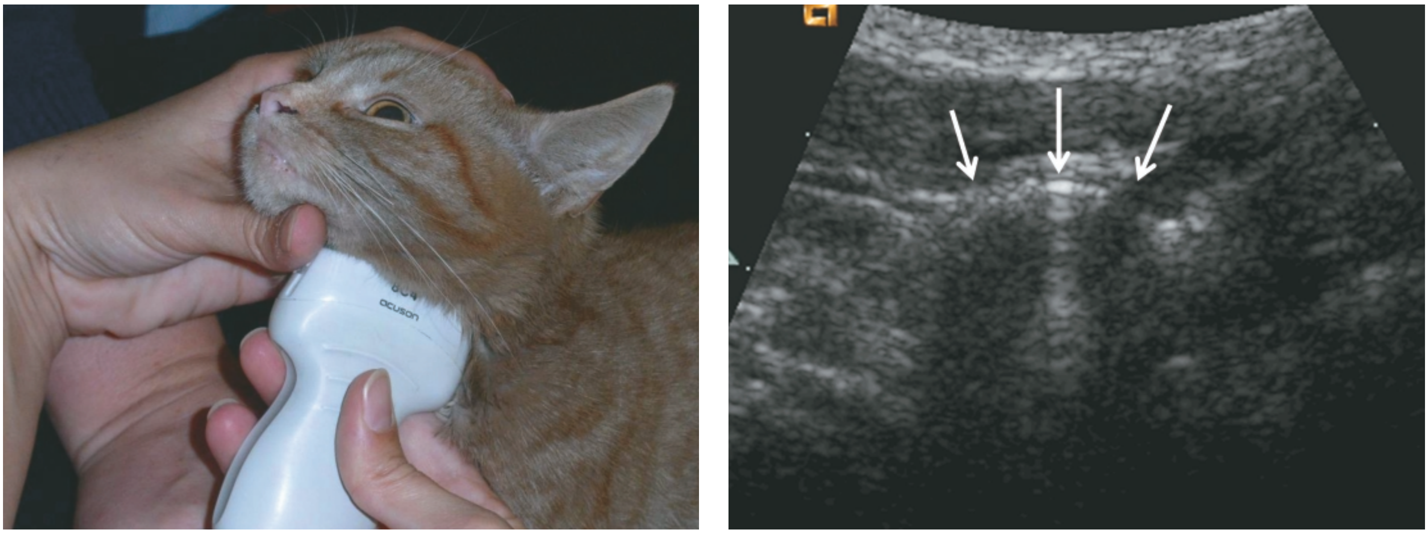
Magnetic resonance imaging (MRI) is a technique that measures radio signals emitted by hydrogen atoms in the body under the influence of a powerful external magnetic field. It is fundamentally different in principle from radiography or CT and, therefore, produces images with very different properties. MRI is preferable to CT for examining the soft tissue components of the external ear, the inner ear and the brain. Normal cortical bone and air contain relatively little hydrogen; hence, each produce a minimal signal and appear black on MRI scans. This makes it difficult to distinguish cortical bone from air, so structures such as the tympanic bullae and paranasal sinuses are difficult to examine using MRI.



CT images of the head of a dog at the level of the ears. CT images may be displayed using different windows according to the tissues of interest. A narrow window (left) enables relatively small differences in tissue attenuation to be displayed, which allows the ventricles to be distinguished from the brain. A wide window (right) displays a much greater range of tissue attenuation and is better suited to examination of the bones of the middle and inner ears. In both windows, the normal tympanic bullae appear air-filled and the mucosal lining is imperceptible



MRI scans of the head of a cat at the level of the ears. Fluid is hypointense (black) in T1-weighted images (left) and hyperintense (white) in T2-weighted images (right). T2-weighted images show the fluid (endolymph and perilymph) contained in the inner ear. In both images, air and cortical bone appear black and cannot be distinguished, which makes it difficult to examine structures such as the tympanic bullae



Ultrasonography of the tympanic bullae. (left) A conscious cat positioned with the transducer on the ventral aspect of the head to examine the left tympanic bulla. (right) Corresponding ultrasound image showing the ventral aspect of the air-filled bulla as a curved echogenic structure (arrows). An acoustic shadow is created at the bone/air interface and a reverberation artefact is produced from the uppermost part of the air/bone interface. In a normal air-filled bulla, the ultrasound waves are reflected and the far wall of the bulla is not visualised

Patients are usually positioned in dorsal recumbency for MRI and images are acquired in the transverse, dorsal and sagittal planes. Precise patient positioning is not necessary because the position and orientation of a series of images is adjusted electronically according to the position of the head in an initial image. A typical MRI protocol for an animal with suspected ear disease includes T1- and T2-weighted transverse images of the head, including the brain, plus additional T1-weighted images after intravenous administration of gadolinium, which acts as a contrast agent (see later).

Principal conditions affecting the ear in dogs and cats

- Otitis externa
- Aural haematoma
- Otitis media secondary to:
  - Otitis externa
  - Cleft palate
  - Inflammatory polyps
  - Brachycephalic conformation
  - Cholesteatoma (congenital or acquired)
- Neoplasia
  - External ear (eg, ceruminous gland adenocarcinoma)
  - Middle ear (eg, carcinoma)
  - Adjacent structures (eg, brain, meninges, bone, salivary glands)
- Otitis interna (eg, lymphocytic labyrinthitis)

INDICATIONS FOR AND LIMITATIONS OF DIAGNOSTIC IMAGING TECHNIQUES

	Radiography	*Computed tomography*	*Magnetic resonance imaging*	*Ultrasonography*
Detect tympanic membrane rupture	++*	+	+++*	–
Detect nasopharyngeal polyps	+	+++	+++	–
Distinguish between fluid and tissue in the middle ear	–	+++†	++†	–
Detect bullae thickening	++	++‡	+++	+
Detect otitis interna	–	++	+	–
Detect associated meningitis	–	++	+	–

– No value, + Limited value, ++ Useful technique, +++ Optimal examination method
*With canalography, †After contrast medium administration, ‡When material is in tympanic bulla

Ultrasonography

Ultrasonography is a novel method for imaging the ear, with certain advantages for clinical use in that it is relatively quick, non-invasive and may be used in conscious patients. In a normal animal, the air within the external and middle ear effectively blocks ultrasound transmission, but if the external ear is deliberately filled with saline or if the middle ear contains fluid or solid material as a consequence of disease, the ultrasound beam may be transmitted through the ear and its internal structure may be examined. For studies of the external auditory canal, the transducer may be placed on the lateral aspect of the head. For examination of the bulla, it is placed on the ventral aspect with the patient in sternal or lateral recumbency. The normal bulla appears as a curvilinear hyperechoic/reflecting line with convexity towards the transducer. An acoustic shadow is created at this reflecting interface and a reverberation artefact is produced.

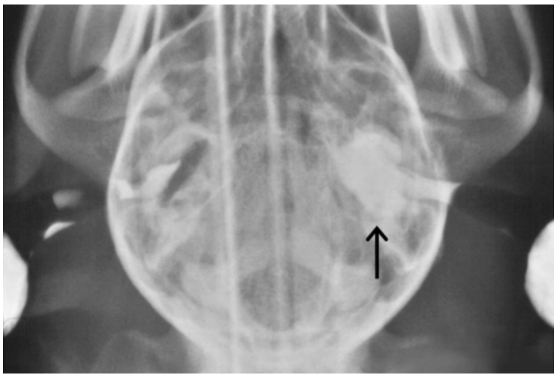
IMAGING MANIFESTATIONS OF EAR DISEASE

The principal aural conditions of dogs and cats are summarised in the box on the left. In animals with otitis externa, there may be accumulation of secretions and exudate in the ear canal and thickening of the aural mucosa due to formation of loose vascular and oedematous granulation tissue. These lesions may be visible using any of the imaging modalities. Chronic otitis externa may result in dystrophic calcification or ossification of the external ear cartilages; however, because calcification is an irreversible process, its presence does not necessarily indicate active inflammation. Imaging is not usually required in cases of uncomplicated otitis externa, unless there is some doubt about the condition of the tympanic membrane.

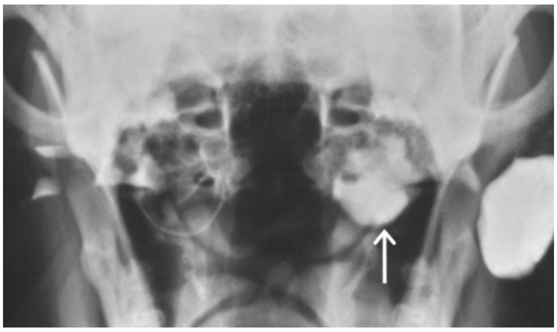
When it is not possible to examine the tympanic membrane adequately by otoscopy (eg, if the canal is too narrow or blocked by exudate), it may be assessed radiographically by infusing contrast medium into the external ear canal. This technique, known as canalography, involves obtaining dorsoventral and rostrocaudal (open-

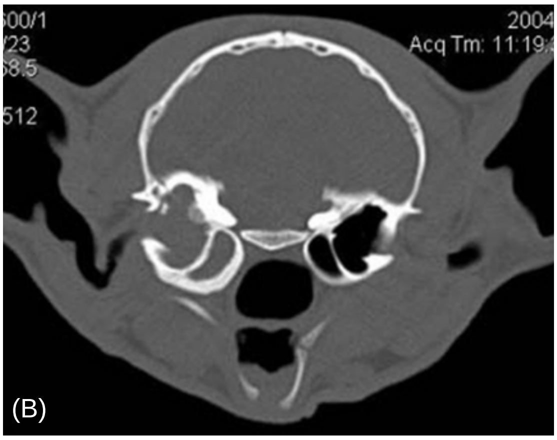
Ventrodorsal radiograph of a dog with bilateral dystrophic calcification or ossification of the external ear cartilages. This appearance is observed in animals with advanced otitis externa

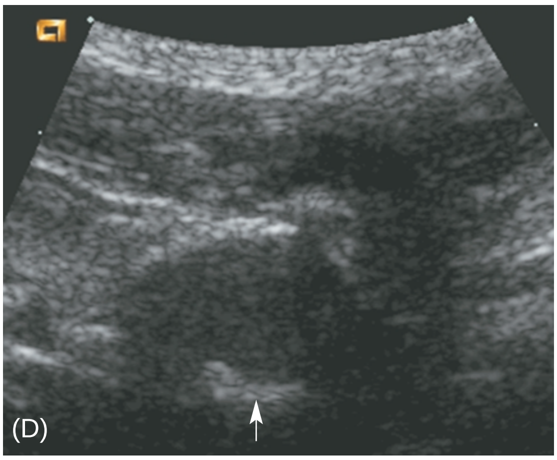
mouth) views of the skull after the infusion of 2 to 5 ml of non-ionic water-soluble iodinated contrast medium into each ear. An intact tympanic membrane prevents contrast entering the tympanic bulla, whereas finding contrast in the bulla proves that the membrane is ruptured even if this was not evident otoscopically. It is easier to recognise small amounts of contrast medium in the tympanic bulla by comparing the contrast image obtained with survey radiographs. Canalography is a simple contrast study that is particularly useful in animals with suspected otitis media but no survey radiographic signs of middle ear disease.



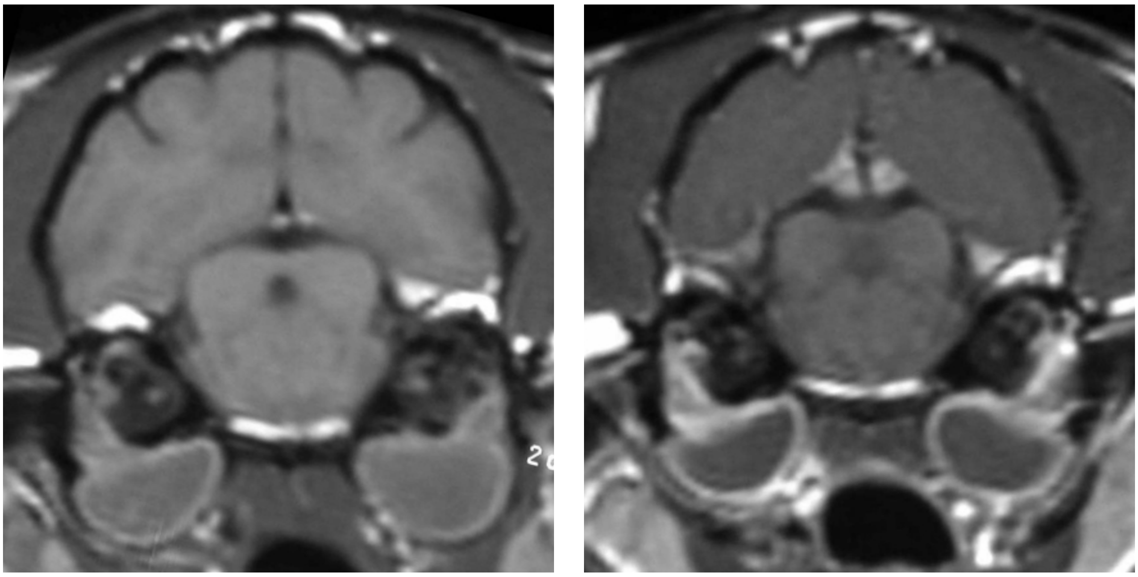
Ventrodorsal (above) and rostrocaudal (below) (open-mouth) radiographs of a dog after bilateral canalography, illustrating the use of canalography to examine the tympanic membrane. The left tympanic bulla is filled with contrast medium (arrows) indicating that the left tympanic membrane is ruptured. Contrast in the right external auditory canal reaches the right tympanic membrane, but does not enter the bulla, suggesting that the right tympanic membrane is intact





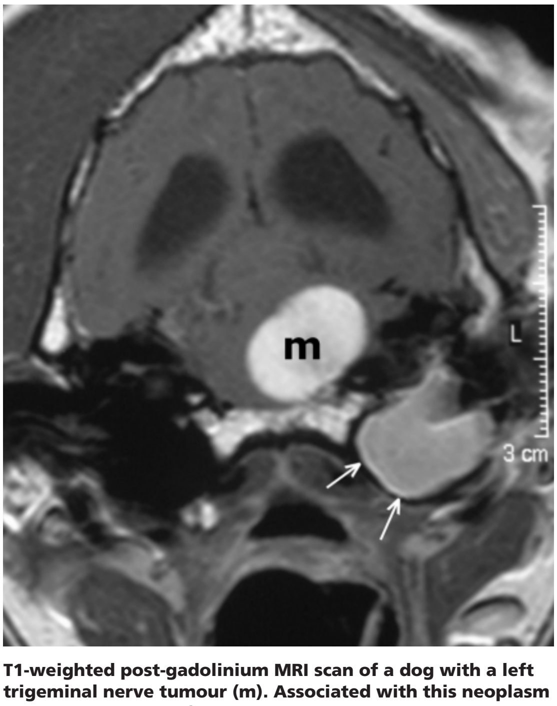


Appearance of otitis media obtained using different imaging modalities. (A) Rostrocaudal (open-mouth) radiograph of a cat with right otitis media showing increased opacity of the right tympanic bulla and thickening of the wall. Associated bilateral narrowing of the external ear canals suggests bilateral otitis externa. (B) CT image of a cat with right otitis media showing material within both compartments of the right tympanic bulla and diffuse thickening of the bulla wall. (C) T2-weighted MRI scan of a dog with left otitis media showing hyperintense material incompletely filling the left tympanic bulla. There is a normal fluid signal from both inner ears, which suggests that there is no otitis interna. (D) Ultrasound image of the bulla of a cat with otitis media; the far wall of the tympanic bulla (arrow) can be visualised because of the presence of fluid within the bulla cavity, which allows transmission of the ultrasound wave through the tympanic bulla



T1-weighted (left) and T1-weighted post-gadolinium (right) MRI scans of a cat with bilateral otitis media. The mucosal lining of the bullae has a higher signal intensity than the material contained in the tympanic cavity, particularly after gadolinium administration, which suggests that it is inflamed

The presence of a ruptured tympanic membrane suggests otitis media. In mild or acute cases, there may be no other imaging signs, but when otitis media becomes chronic, there is usually accumulation of exudate or granulation tissue within the tympanic bulla and/or thickening of the bulla wall. These abnormalities may be visible using any of the available imaging techniques. Radiography is used most often for examining the middle ear in dogs and cats; however, it is relatively insensitive – up to 25 per cent of patients with otitis media have no radiographic signs of disease. CT, MRI and ultrasonography are all more sensitive than radiography for examining the middle ear. CT is considered by many to be the optimal technique for examining the middle ear. On MRI scans, the mucosal lining of the bullae can be distinguished from exudate within the bulla and, on images acquired after the injection of gadolinium, enhancement of the mucosal lining suggests the presence of inflammation.

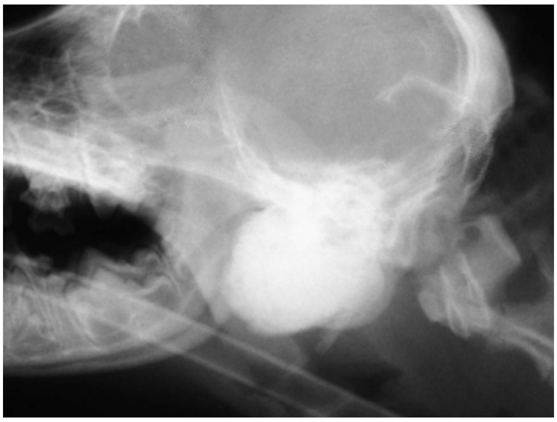


T1-weighted post-gadolinium MRI scan of a dog with a left trigeminal nerve tumour (m). Associated with this neoplasm is marked atrophy of the ipsilateral temporal muscles, and accumulation of homogeneous material in the left bulla (arrows), which is probably a result of auditory tube dysfunction. Reproduced, with permission, from Owen and others (2004)

It is common to observe material – usually fluid – in the middle ear of dogs with no clinical signs of otitis. Accumulation of fluid in the middle ear can occur as a result of auditory tube dysfunction. Normally, the pharyngeal opening of the auditory tube is closed and air pressure within the middle ear is negative (usually in the range 0 to –50 mm water). This negative pressure is generally eliminated when the auditory tube dilates during swallowing, which allows the air pressure in the middle ear to equalise with atmospheric pressure. If opening of the auditory tube is impaired, middle ear pressure becomes progressively more negative as oxygen is absorbed into the bloodstream, and the resulting low pressure draws extracellular fluid into the middle ear. This initially produces a serous effusion that gradually become more proteinaceous and is prone to secondary bacterial infection. Although otitis media often develops by direct extension of otitis externa through a ruptured tympanic membrane, some affected dogs have an intact tympanic membrane. In most dogs, the bacteria in the middle ear differ from those in the horizontal canal, which suggests that the auditory tube is an alternative route for infection reaching the middle ear. Brachycephalic dogs are predisposed to fluid accumulation in the middle ear, probably because these dogs have some form of pharyngeal and/or auditory tube dysfunction. Auditory tube dysfunction also occurs in some dogs with cleft palate, which predisposes them to otitis media. Lesions affecting the trigeminal nerve (which innervates the tensor veli palatini muscle) can also alter auditory tube function.

Low-grade chronic inflammation stimulates a relatively orderly remodelling of the bone forming the wall of the bulla, which frequently results in fairly uniform thickening and sclerosis. Another possible cause of thickening of the bulla is temporomandibular osteopathy, which may be localised to the bullae rather than the mandible.

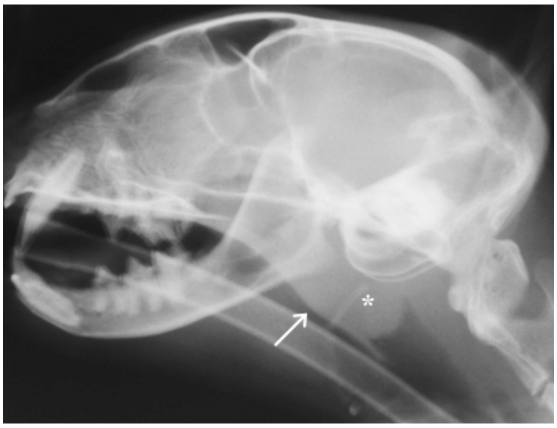
Otoliths appear as well-defined, rounded or ovoid



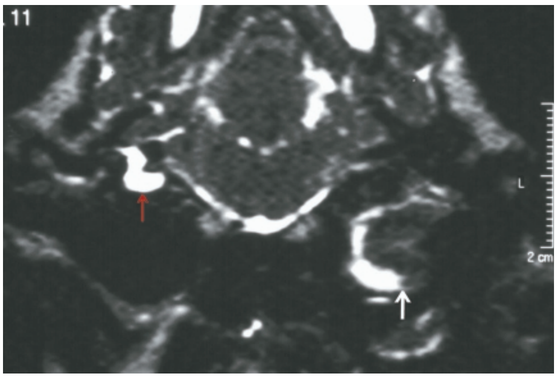
(above) Lateral and (right) rostrocaudal (open-mouth) radiographs of a young dog with temporomandibular osteopathy affecting the tympanic bullae. The walls of the bullae are markedly thickened and opaque as a result of new bone formation, which has impinged on the temporomandibular joints (causing pain on opening the mouth) and the nasopharynx (causing stertor and dyspnoea)

mineral opacities within the tympanic bulla, sometimes associated with thickening of the bulla wall. Their aetiology is unknown. Hypothetically, they may represent dystrophic mineralisation of inflammatory polyps or heterotopic bone formation.

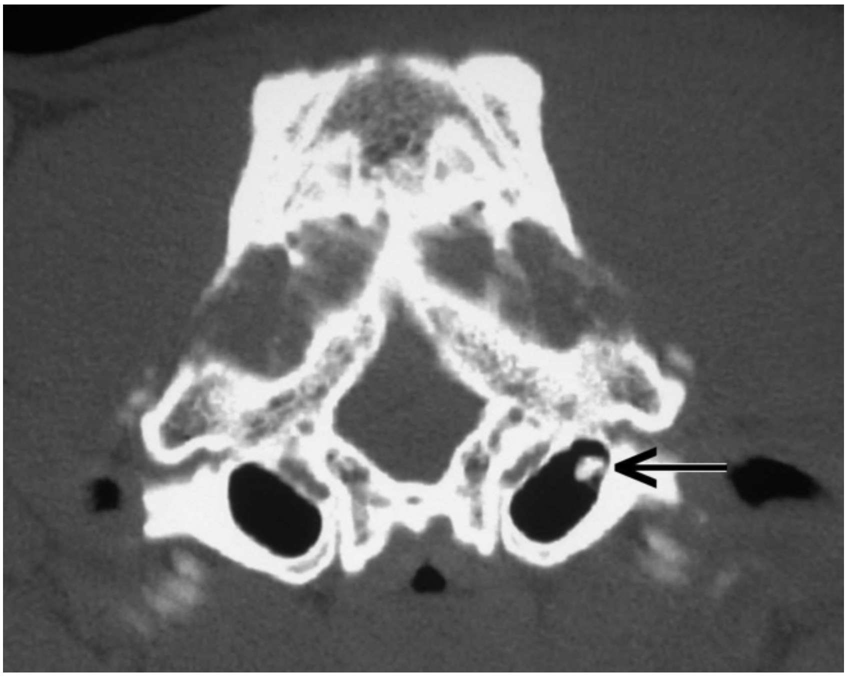
In cats with signs of otitis media, a lateral radiograph of the skull is useful to examine the nasopharynx for



Lateral radiograph of a cat with a large nasopharyngeal polyp, which appears as a rounded soft tissue mass (*) in the nasopharynx that has displaced the soft palate ventrally (arrow)



T2-weighted MRI scan of a dog with left otitis media and suspected otitis interna. There is fluid and other material in the left tympanic bulla (white arrow). The normal fluid signal from the right inner ear is visible (red arrow), but it is absent on the left. Fibrosis associated with chronic inflammation obliterates the fluid spaces in the inner ear and, hence, this appearance strongly suggests left otitis interna

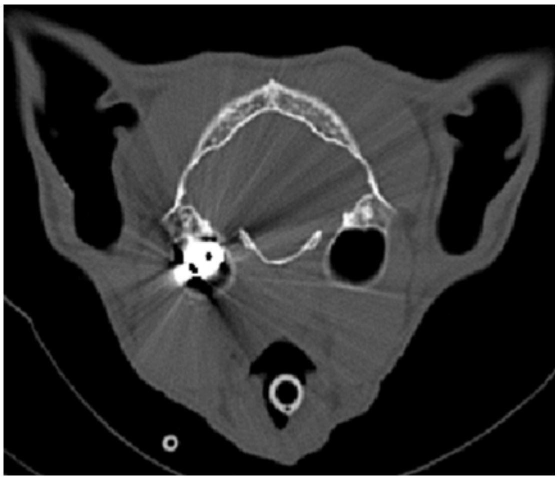


CT image of the caudal aspect of the tympanic bullae in a dog. The focal, ovoid, mineralised structure visible in the left tympanic bulla (arrow) is compatible with an otolith

the presence of nasopharyngeal polyps, which typically appear as rounded intraluminal soft tissue masses that displace the soft palate ventrally.

The inner ear, which is located within the petrous temporal bone, is not visible radiographically as a distinct structure because of superimposition of the surrounding structures. Diagnosis of otitis interna cannot be made on the basis of survey radiographs or ultrasonography. CT and MRI enable more detailed examination of the inner ear. Of these, MRI is probably most useful in animals with vestibular syndrome because it enables optimal examination of both the inner ear and adjacent neural structures. Fibrosis associated with chronic otitis interna may obliterate the spaces in the membranous and bony labyrinths, thus diminishing the magnetic resonance signal from endolymph and perilymph.

Ventrodorsal radiograph of the head of a cat with squamous cell carcinoma affecting the right external auditory canal. There is a soft tissue swelling superimposed on the right external ear canal (*) and lysis of the right temporal bone affecting the base of the zygomatic process and the tympanic bulla (arrows). These signs reflect a much more aggressive process than is usually associated with otitis and, hence, a soft tissue tumour invading bone is a more plausible diagnosis



CT image of a cat with an airgun pellet lodged in the right tympanic bulla. The gun pellet is strongly hyperattenuating (appears extremely bright) and has caused a marked streaking artefact

Neoplasms arising from aural structures are usually locally invasive and may be suspected radiographically when bone destruction and periosteal reaction are observed affecting the tympanic bulla or adjacent structures, including the temporomandibular joint. Obliteration or displacement of the external ear canal and soft tissue swelling of the adjacent regions are other signs that suggest the presence of an aural or para-aural soft tissue mass.

Trauma affecting the tympanic bullae is relatively uncommon because of their protected position, but direct trauma can result in fracture. Occasionally, the ear is affected by gunshot injuries.

WHICH TECHNIQUE?

Radiography remains a popular and useful method for examining dogs and cats with signs of ear disease, but increasing experience with CT and MRI has shown that these cross-sectional techniques have certain advantages. CT appears to be the optimal technique for examining the middle ear, but it has not been directly compared with MRI. MRI is a sensitive method for examining the inner ear and adjacent neural structures. Ultrasonography has potential as a method for rapid assessment of the middle ear in conscious patients.

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