Clinical and Surgical Management of Pediatric Diseases of the Ear and Temporal Bone

4

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Introduction

As is well known, the external ear is comprised of the pinna and ear canal which is separated from the air containing middle ear cleft by the tympanic membrane. For the purpose of hearing, energy from sound waves impacting the tympanic membrane is transmitted across the middle ear space by the ossicular chain into the cochlea. The temporal bone provides the bony framework for these structures and functions. It is situated on the lateral aspect of the skull base and comprises four parts. The largest is the squamous part, which makes up the part of the calvarium above the ear canal. The petrous part of the temporal bone contains the sensory apparatus of the cochlea and vestibular system. It is approximately conical with the apex pointing toward the center of the skull base. The mastoid part forms the bony prominence behind the ear canal. The tympanic ring is the smallest part of the temporal bone and makes up most of the bony part of the external ear canal. The internal carotid artery, jugular vein and facial, cochlear and vestibular nerves pass through the temporal bone. The trigeminal, abducens, and bulbar nerves all lie in close proximity. Dysfunction of any of these structures may be caused by temporal bone pathology.

A variety of benign and malignant pathologies can affect the temporal bone in childhood. Clinical features of these disorders overlap: hearing loss and otorrhea, even bleeding from the ear from an aural polyp, are very nonspecific symptoms that can be caused by many different pathologies. Otalgia, swelling around the ear, and facial nerve or other cranial nerve palsy are more strongly suggestive, but not diagnostic, of malignant disorders. However, as is described below, neoplastic disorders of the temporal bone are exceptionally rare in childhood. Published experience of many such disorders is limited to small series or even case reports, and experience at the Hospital for Sick Children over the last 15 years is often limited to individual cases.

In comparison, cholesteatoma is relatively common with many hundred cases being seen over this time period. Although the histology of cholesteatoma may provide little challenge for the pathologist, cholesteatoma is covered in some depth in this chapter because of its prevalence and challenging behavior. Although the pathology of cholesteatoma is benign, the disease is proliferative, locally invasive, and destructive with high propensity to recidivism. It is the commonest cause of permanent conductive hearing loss in children and carries the risk of facial palsy and life-threatening suppurative complications.

Tympanosclerosis

Definition

Tympanosclerosis is a condition in which hard white plaques form within the middle layer of the tympanic membrane or elsewhere in the middle ear cleft. It is most commonly confined to the tympanic membrane alone, in which location it is more correctly referred to as myringosclerosis. Although the term tympanosclerosis is often used to describe lesions confined to the tympanic membrane, for the sake of clarity in this chapter, "tympanosclerosis" is used to describe the condition within the middle ear, and "myringosclerosis" lesions confined to the tympanic membrane.

The severity of tympanosclerosis has been categorized into clinically relevant stages based on the extent of ossicular involvement as, for example, by Wielinga and Kerr [1]:

- Type I: tympanic membrane involvement (i.e., myringosclerosis).
- Type II: attic fixation of the malleus-incus complex with a mobile stapes.

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- Type III: isolated stapes footplate fixation.
- Type IV: fixation of the stapes footplate and the malleus-incus complex.

The pathogenesis is thought to begin with invasion of fibroblasts into the submucosal plane, followed by condensation of collagen fibers within which calcium deposits collect. This process is also referred to as hyalinization. It is rarely seen without a history of prior ear disease. Randomized controlled trials of children with otitis media with effusion show that myringosclerosis occurs in around one-third of ears after tympanostomy tube insertion compared with <1% of ears in control groups [2]. It is said to be slightly more common in males [3].

Clinical Presentation

In the majority of children, myringosclerosis has no clinical significance. It is usually detected as an incidental finding during otoscopy with the characteristic appearance of a fairly bright white plaque within the tympanic membrane (Figs. 4.1a and 4.1b).

The shape, size, and density of the lesion vary. Commonly, it forms a crescentic shape, often sparing the atrophic circular area where a tympanostomy tube was formerly situated. The outline is sharply defined, and may be irregular, especially with thinner lesions, or smooth, especially with dense lesions. As myringosclerosis lies within the fibrous middle layer of the tympanic membrane it is typically flat, and does not disrupt the usually flattened-cone shape of the tympanic membrane. Myringosclerotic plaques are hard and this can be revealed by palpation with a fine probe. As contact with the tympanic membrane is usually tender, hardness is more easily assessed under general anesthesia. It is very rare for myringosclerosis to completely cover the tympanic membrane and as a result it does not usually cause hearing loss in children. By stiffening the tympanic membrane, myringosclerosis segments resist retraction in the presence of negative middle ear pressure. However adjacent segments of atrophic, or even normal, pars tensa may retract (Fig. 4.1b). The opacity of myringosclerosis prevents assessment of the depth or contents of retractions that extend underneath so can hide cholesteatoma.

Tympanosclerosis within the middle ear is much less common than myringosclerosis in children. When present, it can partially or more completely encase ossicles and cause conductive hearing loss. Sometimes it can be seen and recognized through a tympanic membrane perforation (Fig. 4.1c) but if the tympanic membrane is intact, the diagnosis of middle ear tympanosclerosis is difficult without surgical exploration.

The presence of myringosclerosis is so much more common, it is not a reliable guide to the likelihood of finding tympanosclerosis in the middle ear. Reduction of compliance measured with tympanometry and an air-bone gap on pure tone audiometry are clues to the presence of tympanosclerosis, especially if the child is known to have had normal hearing previously (e.g., on newborn hearing screening), has no history of temporal bone trauma and no evidence of an effusion, tympanic membrane retraction, or cholesteatoma.

Radiological Features

CT scan may reveal larger plaques of tympanosclerosis with a density between that of bone and soft tissues (Fig. 4.1d).

Differential Diagnosis

Most importantly, the differential diagnosis of white lesions seen through the eardrum includes congenital cholesteatoma (see below). On occasion it can be difficult to distinguish these two conditions with otoscopy, but there are some characteristic differences. Tympanosclerosis typically has a brighter less cream colored appearance. Small congenital cholesteatomas are spherical so the edge dips away from the tympanic membrane. The drum may be pushed up and bulge with larger cholesteatomas. As cholesteatoma is soft to palpation, it should not be necessary to cut into the lesion with a myringotomy to make the diagnosis: tympanosclerosis resists incision, but cholesteatoma will be opened creating a fistula from cyst lining to eardrum surface that makes surgical excision more complex [4].

Whiteness within the tympanic membrane is also caused by use of cartilage as a graft in tympanoplasty. Usually this will be known from the child's medical history. Surgical scars (postauricular, end-aural or on the posterior surface of the tragus or pinna) obviously provide clues to this possibility, but the appearance is usually sufficiently obvious.

Management

Asymptomatic tympanosclerosis requires no treatment. It is the preference of some surgeons to remove myringosclerotic plaques when repairing tympanic membrane perforations surgically, but there is no good evidence to show this alters the success of surgery.

Hearing aids should certainly be considered for rehabilitation of tympanosclerosis causing hearing loss. The surgical management of tympanosclerosis causing conductive hearing loss remains controversial, particularly with extensive involvement of the stapes. Some authors have reported clinically significant improvements in hearing, predominantly in adults, after removal of tympanosclerotic plaques for limited disease or ossiculoplasty for more extensive disease [3, 5–7]. Partial sensorineural hearing loss occurs occasionally after such surgery. Long-term follow-up is associated with recurrence of conductive hearing loss in a small proportion of cases.

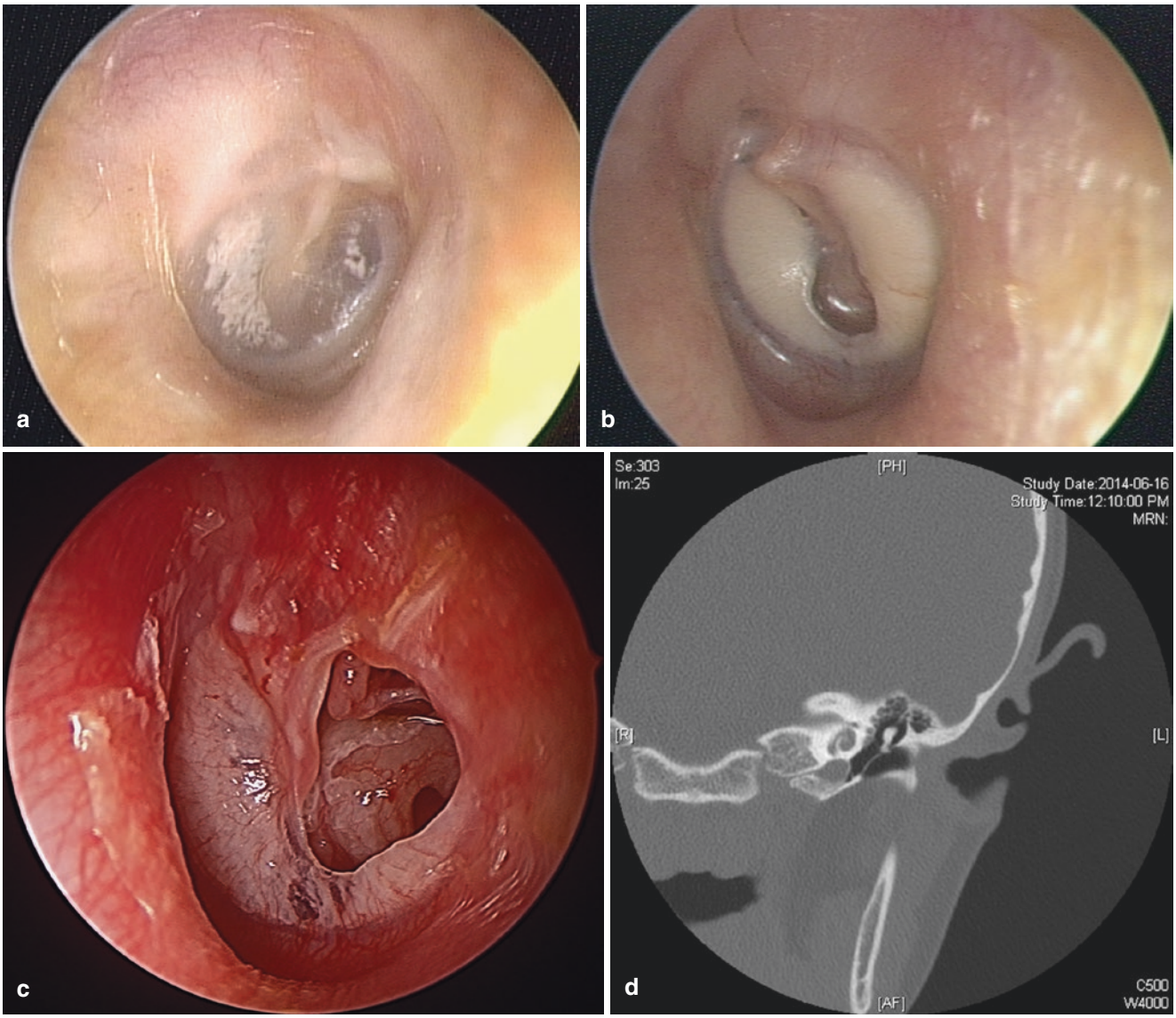


Fig. 4.1 (**a**) Myringosclerosis of the right tympanic membrane. (**b**) Myringosclerosis of the left tympanic membrane also showing retraction of the non-affected central portion pars tensa. (**c**) Tympanosclerosis of the left tympanic membrane as well as the middle ear seen through a large central perforation. (**d**) Coronal CT showing myringosclerosis of the tympanic membrane

Cholesteatoma

Definition

Cholesteatoma is most simply defined as "skin in the wrong place." Like the skin covering the eardrum, it contains no adnexa and can be defined more precisely as a growth of keratinizing squamous epithelium in an abnormal area of the tympanomastoid system. It comprises three parts: (1) desquamated keratin debris which forms the contents of the lesion and typically the majority of its volume and is derived from (2) squamous epithelium, which is also referred to as "matrix" and (3) "perimatrix" which surrounds the matrix, is derived from middle ear mucosa and may become inflamed with formation of granulation tissue. Different categories of cholesteatoma are recognized clinically, but cannot be distinguished histologically.

Congenital cholesteatoma arises from a collection of ectopic keratinizing squamous cells medial to a normal tympanic membrane. As demonstrated by Teed and confirmed by Michaels, the nidus is likely a remnant of the epibranchial placode, an ectodermal structure that buds off the tympanic membrane in early fetal life and usually disperses [8, 9]. It has been categorized into petrous apex, mastoid, and tympanic types, with the latter being by far the most common [10]. Congenital cholesteatoma is usually cystic (Fig. 4.2a).

Acquired cholesteatoma is an ingrowth of skin from the tympanic membrane, or less commonly the ear canal. A *primary* acquired cholesteatoma grows from retraction of the pars tensa or pars flaccida (Figs. 4.2b and 4.2c).

In children, cholesteatoma arises from the pars tensa retraction twice as often as from the pars flaccida, whereas in adults pars flaccida is the more common site of origin. S*econdary* acquired cholesteatoma arises from implantation of squamous epithelium by surgery or trauma to the eardrum or canal, or from ingrowth around the margin of a perforation. In the author's experience this is much less common than primary acquired disease. It is of note that a thin atelectatic tympanic membrane may perforate (Sade stage V) [11], and that cholesteatoma may grow from viable remnants of the retracted drum remaining in the middle ear space. Observation of many children with tympanic membrane retraction leads to the impression this is a more common cause of cholesteatoma with perforation than the secondary acquired pathogenesis.

Precholesteatoma

A tympanic membrane retraction pocket becomes an acquired cholesteatoma when it loses self-cleaning capacity and begins to accumulate keratin debris, or if granulation tissue (perimatrix) forms within it. Treatment with microdebridement and topical therapeutics may (if only temporarily) restore it to the state of a clean tympanic membrane retraction pocket. This precarious state in between retraction and cholesteatoma has the potential to progress irreversibly into cholesteatoma so can be thought of as "precholesteatoma." It is important to be aware that some retracted eardrums may recover the ability to self-clean by spontaneous lateralization of the retraction or following erosion of bone which saucerizes the sharp edges of the pocket.

Disease recidivism is common after cholesteatoma surgery and it is important to distinguish residual from recurrent forms. **Residual cholesteatoma** is a disease that grows from remnants of matrix that were incompletely removed at surgery. This is most commonly found as a cystic structure, though it can occasionally form *en plaque* sheets of disease in the ear. The squamous epithelium of residual cholesteatoma is not continuous with the surface of the eardrum (Fig. 4.2d).

Recurrent cholesteatoma is a disease that grows from a new retraction after previous cholesteatoma surgery. It can easily be distinguished from residual disease as the matrix lining the sack of disease is in continuity with skin on the surface of the eardrum and ear canal. Both residual and recurrent disease can occur in the same ear. The risk of each is said to be higher in children than in adults [12].

Indeterminate Origin

It is recognized that the drum of an ear with congenital cholesteatoma may become perforated by other means, such as myringotomy or acute otitis media, also that congenital cholesteatoma may rupture through the eardrum. In such cases, it can be difficult to confirm whether the origin is congenital or acquired [13]. The distinction between primary and secondary acquired cholesteatoma can also be difficult, for example, when cholesteatoma arises in a retracted perforated drum. Cholesteatoma found after tympanoplasty might be residual disease or secondarily acquired from surgical implantation.

Clinical Presentation

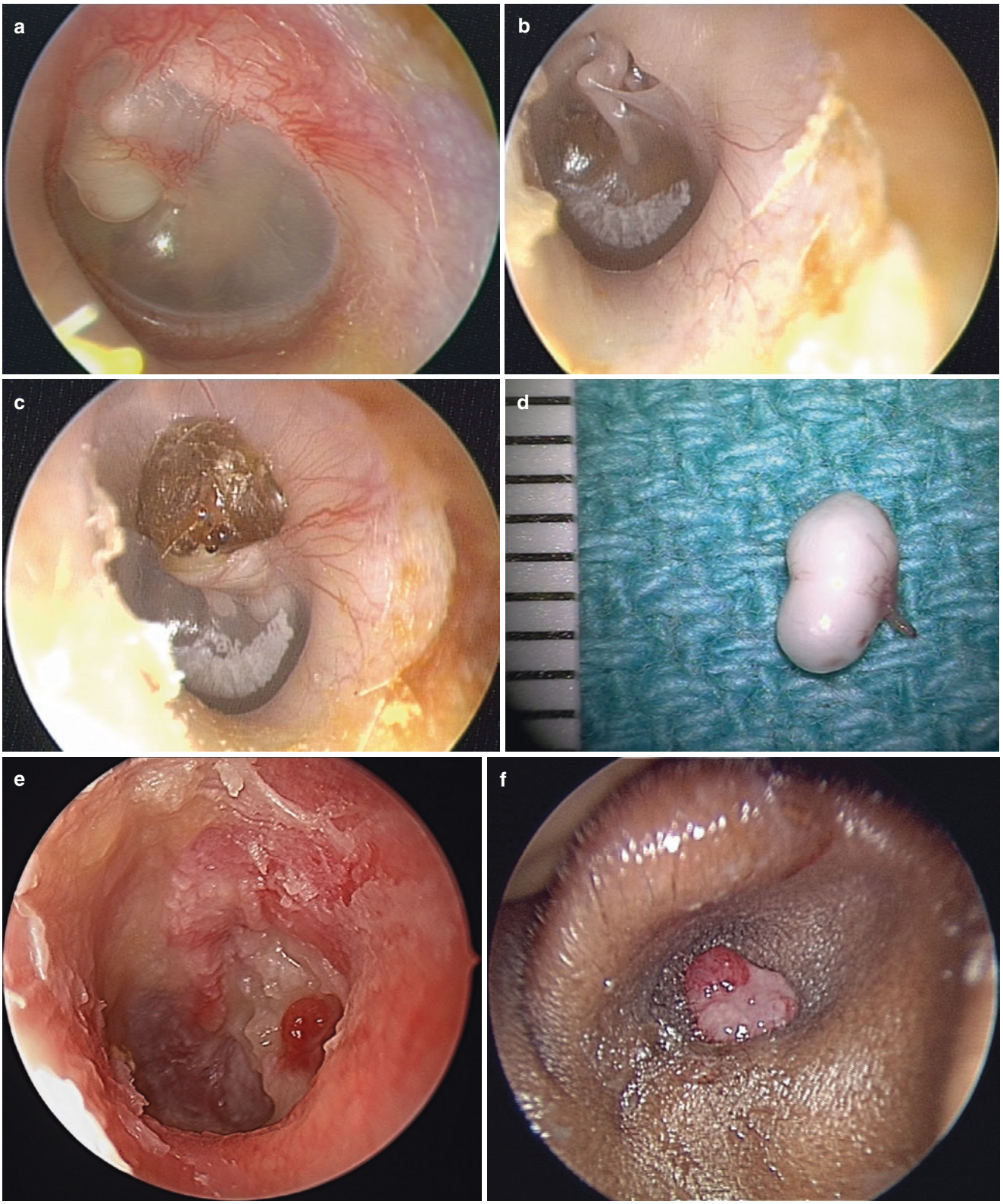
The classic features of cholesteatoma are unilateral painless odorous discharge and hearing loss, but cholesteatoma in children may be silent with insidious onset and growth. Discharge is only seen when acquired cholesteatoma is infected and the unilateral hearing loss often passes unnoticed by young children and their parents. Cholesteatoma may thus be extensive at the time of presentation unless detected early by vigilant otoscopy. It is present in both ears in a minority of children.

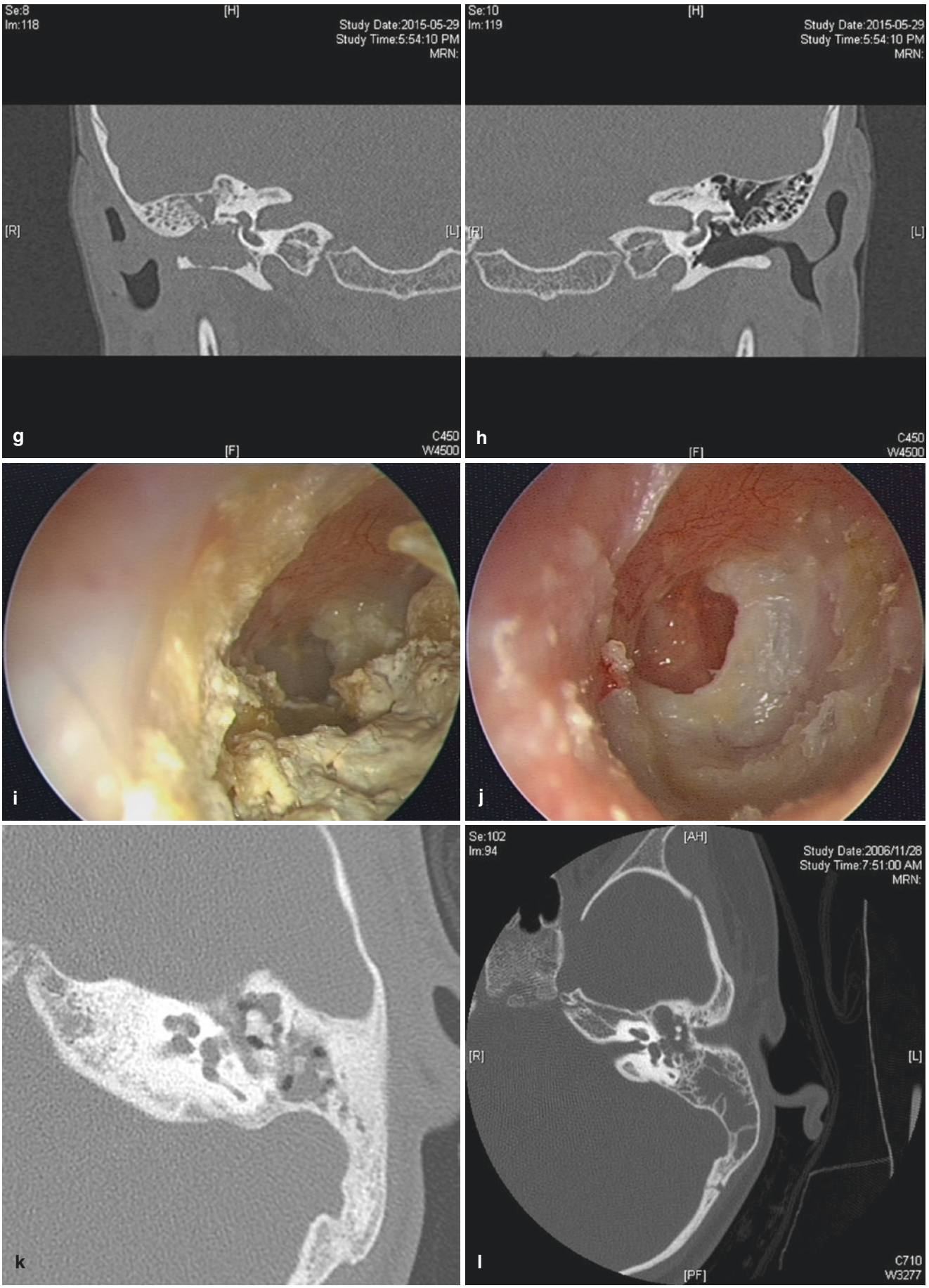
The classic otoscopic appearance of a congenital cholesteatoma is of a pearly white mass under the anterosuperior quadrant of a normal tympanic membrane (Fig. 4.2a) [10, 13]. It may also arise in the posterosuperior quadrant of the middle ear. With time it will grow to fill the middle ear space and indeed the mastoid. Hearing loss is caused by ossicular involvement, especially erosion, or by concomitant otitis media with effusion (OME) which may be

Fig. 4.2 (**a**) Congenital cholesteatoma of left ear as seen on otoscopy. A white "cystic" mass is seen behind a normal appearing tympanic membrane in the anterior superior quadrant. (**b**) A clean retraction pocket is seen in the pars flaccida of the left tympanic membrane in a child with otitis media with effusion. Myringosclerosis is also seen as white plaques on the pars tensa. (**c**) A cholesteatoma of the left ear originating from a deep pars flaccida retraction. The pocket is also covered by a "wax-like" material. Tympanosclerosis is also seen in the lower part of the pars tensa. (**d**) Gross appearance of a removed "pearl-like" residual cholesteatoma. (**e**) Pus and moist white keratin debris on the left tympanic membrane with "fleshy" granulation tissue. (**f**) Aural polyp of granulation tissue. (**g**) Coronal CT showing expansion and erosion of the right ear canal in keratosis obturans. (**h**) Coronal CT of left temporal bone showing expansion and erosion of the external canal caused by long-standing wax impaction and ultimately development of keratosis obturans. (**i**) Chronic accumulation of wax and keratin debris in the external ear canal seen in keratosis obturans. (**j**) Bony erosion secondary to chronic accumulation of keratin debris in the external ear canal as seen in keratosis obturans. (**k**) Axial CT of left temporal bone with scalloping into bone strongly suggestive of cholesteatoma. (**l**) Axial CT of a left temporal bone with scalloping into bone and rounded edges of the soft tissue in the anterior middle ear is strongly suggestive of cholesteatoma. (**m**) Coronal CT of extensive right temporal bone cholesteatoma with thinning and erosion of the normal covering of bone over the carotid artery. (**n**) A normal appearing coronal CT in a child with bilateral cholesteatoma and chronic otorrhea. The keratinous contents of cholesteatoma have liquefied with infection and discharge into the ear canal, leaving an empty, air-containing pocket that may not be detected on CT

associated with obstruction of the Eustachian tube by the lesion.

Acquired cholesteatoma is said to develop after a history of recurrent acute otitis media (rAOM) or OME in young childhood, but careful history-taking reveals that many children have no such prior history. Cleft palate is the strongest risk factor for the development of acquired cholesteatoma [14]. A positive family history of cholesteatoma and other syndromic associations are rare. When cholesteatoma is infected, otoscopy may reveal pus and moist white keratin





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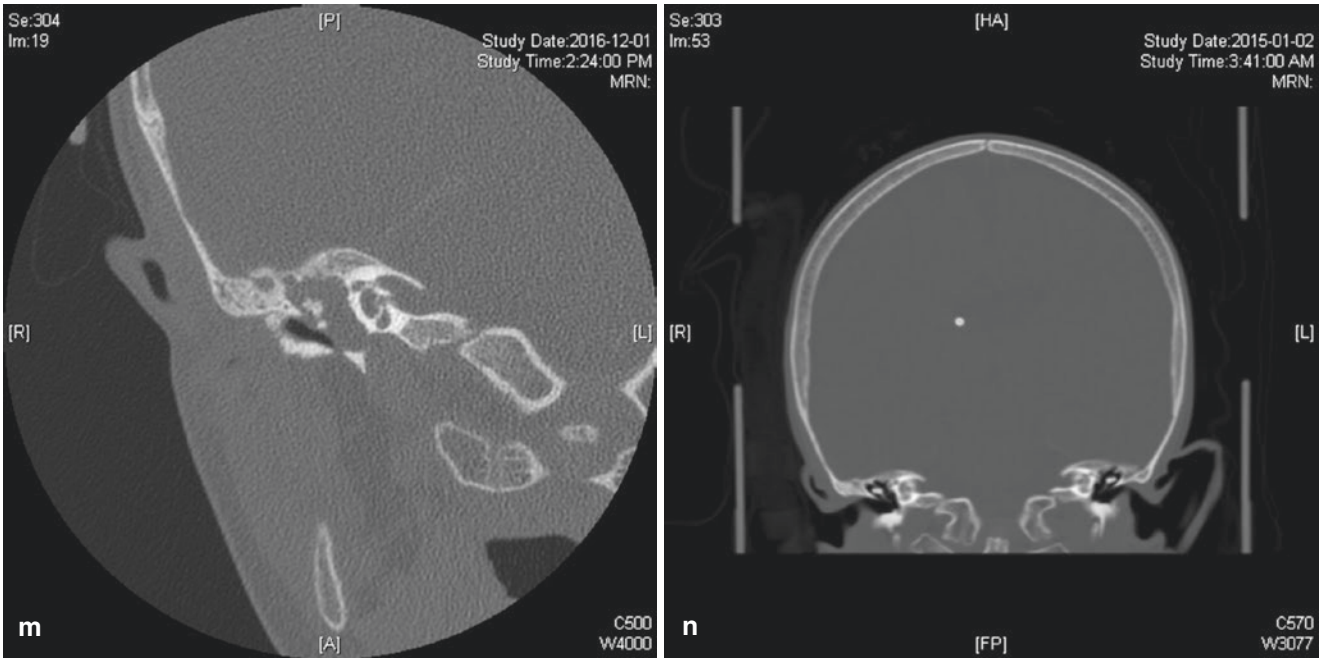


Fig. 4.2 (continued)

debris, with or without granulation tissue (Fig. 4.2e). This may obscure a clear view of the eardrum or be seen within a retracted area of pars tensa or flaccida. Dry keratin looks like wax, so a noninfected acquired cholesteatoma may be hidden from view by a crust of waxy material across the opening of the retraction (Fig. 4.2c).

On occasion, cholesteatoma presents in childhood with more serious complications of the disease than conductive hearing loss from ossicular erosion. Intracranial complications include sepsis (such as cerebral or extradural abscess) and sigmoid sinus thrombosis. Intratemporal complications include labyrinthine fistula (most commonly into the lateral semicircular canal) and facial nerve palsy. Extracranial spread of infection can cause abscess formation.

Differential Diagnosis

It is important for clinicians to distinguish between otorrhea from cholesteatoma and that from rAOM. Other symptoms associated with AOM, such as malaise, otalgia, and fever, are not typical of cholesteatoma (in the absence of suppurative complications). AOM usually occurs in younger children and without smelly otorrhea, but the clinician cannot rely on these presenting features to make the diagnosis. It is necessary to carefully clean and inspect the entire pars flaccida and pars tensa before cholesteatoma can be excluded so a follow-up visit to see the child after treatment of infection may be required.

On occasion, cholesteatoma will present with an aural polyp of granulation tissue (Fig. 4.2f).

This can also be caused by keratosis obturans or wax impaction, conditions in which keratin debris trapped in the ear canal can generate chronic infection and erosion of adjacent bone (Figs. 4.2g, 4.2h, 4.2i and 4.2j). This is also known as "wax keratosis".

Bloody otorrhea is more commonly from granulation tissue or an aural polyp associated with cholesteatoma than from neoplasia. Unlike temporal bone neoplasia, cholesteatoma is unlikely to cause swelling around the ear though occasionally it presents with features of acute mastoiditis from spread of infection.

Congenital cholesteatoma filling the middle ear gives the eardrum a white appearance that may be mistaken for myringosclerosis [4]. A cartilage graft used in tympanoplasty also gives a white appearance to the eardrum.

Radiological Features

CT scan is commonly utilized in pediatric cholesteatoma to evaluate the relationship between cholesteatoma and the individual's tympanomastoid anatomy for planning the surgical approach to treatment. It is also valuable for revealing complications including labyrinthine fistula and, if contrast is used, intracranial sepsis or thrombosis. As the CT features of cholesteatoma can be fairly nonspecific, scanning is generally more useful for these purposes than for confirming the diagnosis. Cholesteatoma is isodense with soft tissue on CT so

cannot reliably be distinguished from middle ear effusion or granulation tissue but a rounded edge to the soft tissue lesion, either bulging into an air space or scalloping into bone is strongly suggestive of cholesteatoma (Figs. 4.2k and 4.2l).

Ossicular erosion of the long process of incus is commonly seen, but the stapes superstructure is too thin to be reliably detected within cholesteatoma. The scutum may be eroded in the minority of pediatric cholesteatomas arising from pars flaccida retraction, but can also be eroded in clean retraction pockets. CT can also detect thinning or complete erosion of bone covering critical structures such as the carotid artery, very important for preoperative planning (Fig. 4.2m).

Poor development of mastoid pneumatization is the most consistent feature of acquired cholesteatoma on temporal bone imaging.

Cholesteatoma gives a bright signal on T2-weighted MRI and a dull signal on T1. Non-echoplanar diffusion-weighted imaging gives a bright signal from cholesteatoma and has been used increasingly to screen for residual cholesteatoma [15]. It can also be used preoperatively to assess the extent of cholesteatoma more accurately than CT alone.

The keratinous contents of cholesteatoma may liquefy with infection and discharge into the ear canal, leaving an empty, air-containing pocket that cannot be detected with temporal bone imaging (Fig. 4.2n).

The limits of retraction of a recurrent cholesteatoma may also grow more quickly than the pocket fills with keratin so not be detectable with imaging.

Management

The fundamental basis of cholesteatoma treatment is to surgically remove the lesion in order to prevent destructive growth and suppurative complications. Historically, the aim of surgery was simply to achieve a safe dry ear. This can be achieved with a modified radical mastoidectomy in which a mastoid cavity is opened into a widened ear canal and most of the ossicular chain removed. The principal disadvantages of this approach are the requirement for clinic-based debridement of the mastoid cavity which is often poorly tolerated by children, and to some extent worse hearing [16]. Current surgical techniques strive to leave the child with a functionally and aesthetically more normal ear [17]. Endoscopic surgery can facilitate a minimally invasive surgical approach through the ear canal [18]. Laser and endoscopes can be used to reduce the risk of residual disease [19, 20]. Use of cartilage tympanoplasty and obliteration of the mastoid may help to prevent recurrent cholesteatoma [21–23].

Consideration should also be given to rehabilitation of hearing loss, either with assistive devices such as hearing aids or surgical reconstruction (ossiculoplasty). However the results of ossiculoplasty are frequently disappointing, and many adolescents do not perceive a need to wear a hearing aid for unilateral conductive hearing loss [24].

The ideal endpoint of a self-cleaning ear canal with normal hearing, and no risk of recidivistic disease can sometimes be achieved by a single stage of surgery, but generally only in the favorable setting of limited disease at presentation. As the prospect for achieving a normal ear is much greater with less extensive disease, strategies to encourage early identification and treatment should be encouraged.

Middle Ear Hemangioma

Definition

Hemangiomas are benign tumors of blood vessels with many different characteristic types and behaviors. They occur very rarely in the temporal bone: a recent review found a total of only 13 reported cases, with the majority occurring in adults [25, 26]. The International Society for the Study of Vascular Anomalies has most recently classified vascular anomalies in 2015, reinforcing the distinction between proliferative vascular tumors, which includes various types of hemangioma, and relatively static vascular malformations [27]. It appears that this distinction has been respected in reports of temporal bone hemangiomas at least since the 1980s, though not without controversy [26, 28]. Reported cases are consistent with the current phenotypic classification of benign, non-involuting, locally aggressive hemangioma.

Infantile hemangioma, a progressive but ultimately involuting lesion presenting within a few months of birth, occurs relatively commonly in proximity to the ear. Compression and obstruction of the ear canal can result. These lesions have not been reported as arising within the temporal bone so are not addressed further in this chapter.

Clinical Presentation

The few pediatric cases reported include presentation at 6, 12, and 14 years old with all lesions arising in the mastoid [26, 28, 29]. In one of these cases, a seemingly separate lesion was present in the ipsilateral middle ear. Conductive hearing loss is the most common symptom from hemangioma in the middle ear, either by a space-occupying effect or ossicular erosion [26, 28]. Pulsatile tinnitus may also occur. Facial nerve twitching or paralysis may result from lesions arising at the geniculate ganglion or within the internal auditory meatus, the latter site also causing sensorineural hearing loss, but of note, these locations and presentations seem to have been reported only in adults [26, 30]. Bleeding from the ear canal or intracranially has also been reported in adults [26]. When visible on otoscopy a dull reddish mass is seen (Fig. 4.3a).

Locally invasive growth rather than involution is anticipated for hemangiomas within the temporal bone.

Differential Diagnosis

On account of the rarity of this condition, diagnosis might not be suspected preoperatively [28, 31]. It can be mistaken for glomus tympanicum [25], but this condition is also extremely rare in childhood. An aberrant internal carotid artery provides a surprisingly similar and considerably more hazardous pitfall for misdiagnosis, which strongly emphasizes the imperative for appropriate preoperative imaging (Figs. 4.3b, 4.3c and 4.3d).

Aural polyp, cholesterol granuloma, rhabdomyosarcoma, and high jugular bulb have also been listed in the differential diagnosis [32].

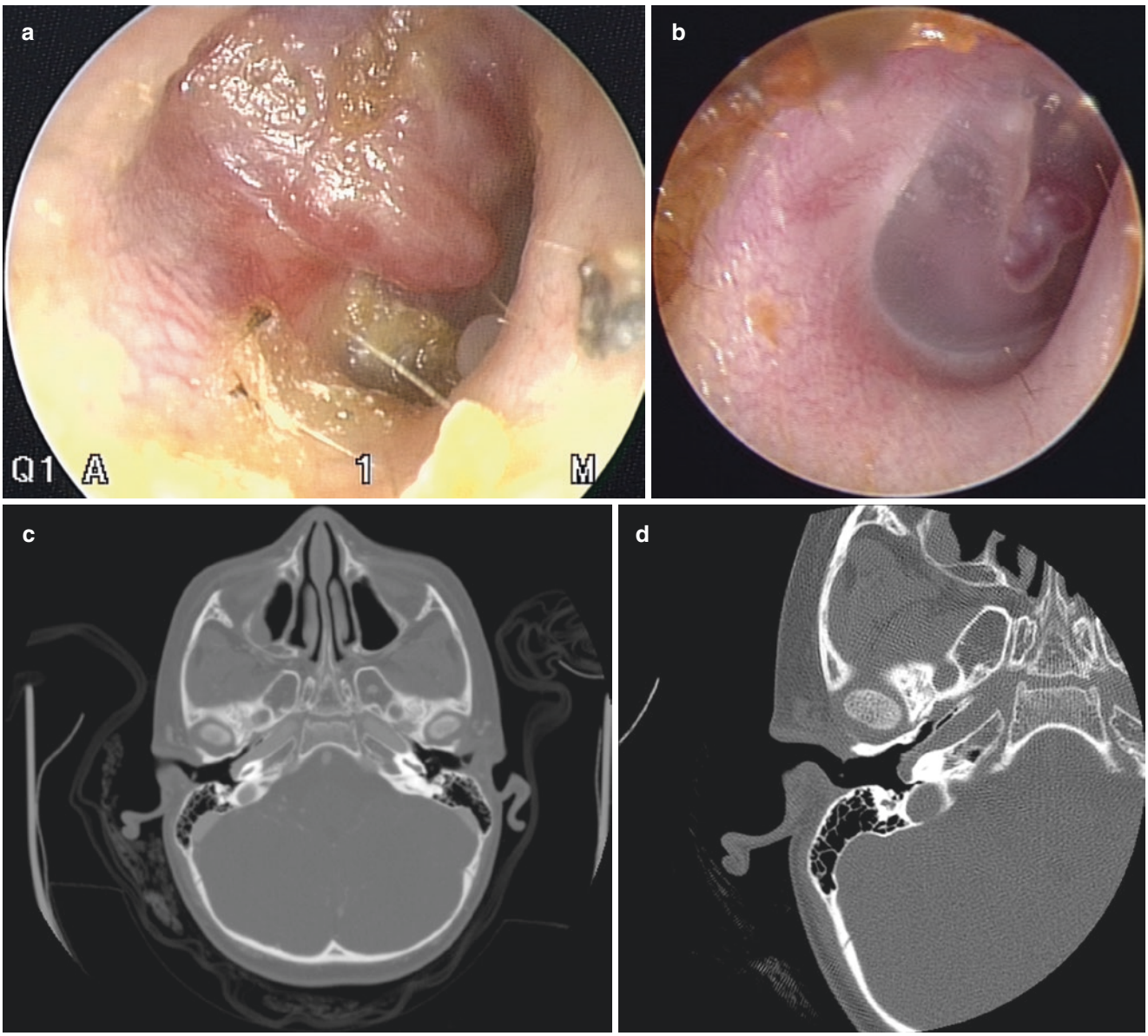


Fig. 4.3 (**a**) A dull reddish mass behind the eardrum on otoscopy from a haemangioma. (**b**) Reddish mass behind the right tympanic membrane is an aberrant internal carotid artery. (**c**) Axial CT of the head and temporal bones showing an aberrant course of the right internal carotid artery. The left carotid canal is normal and covered by bone. The normal bony cover of the carotid artery is absent on the right. This was detected on otoscopic exam as a reddish mass behind an intact otherwise normal appearing tympanic membrane. (**d**) Axial CT of left temporal bone showing close up view of the aberrant course of the carotid artery. (**e**) Coronal CT in a child with hemangioma. Despite showing extensive soft tissue mass, no erosion of the bony scutum or expansion of bone is seen. (**f**) Coronal T2 MRI showing high-intensity bright signal of hemangioma of right ear canal. (**g**) Coronal T1 MRI with gadolinium showing moderate enhancement

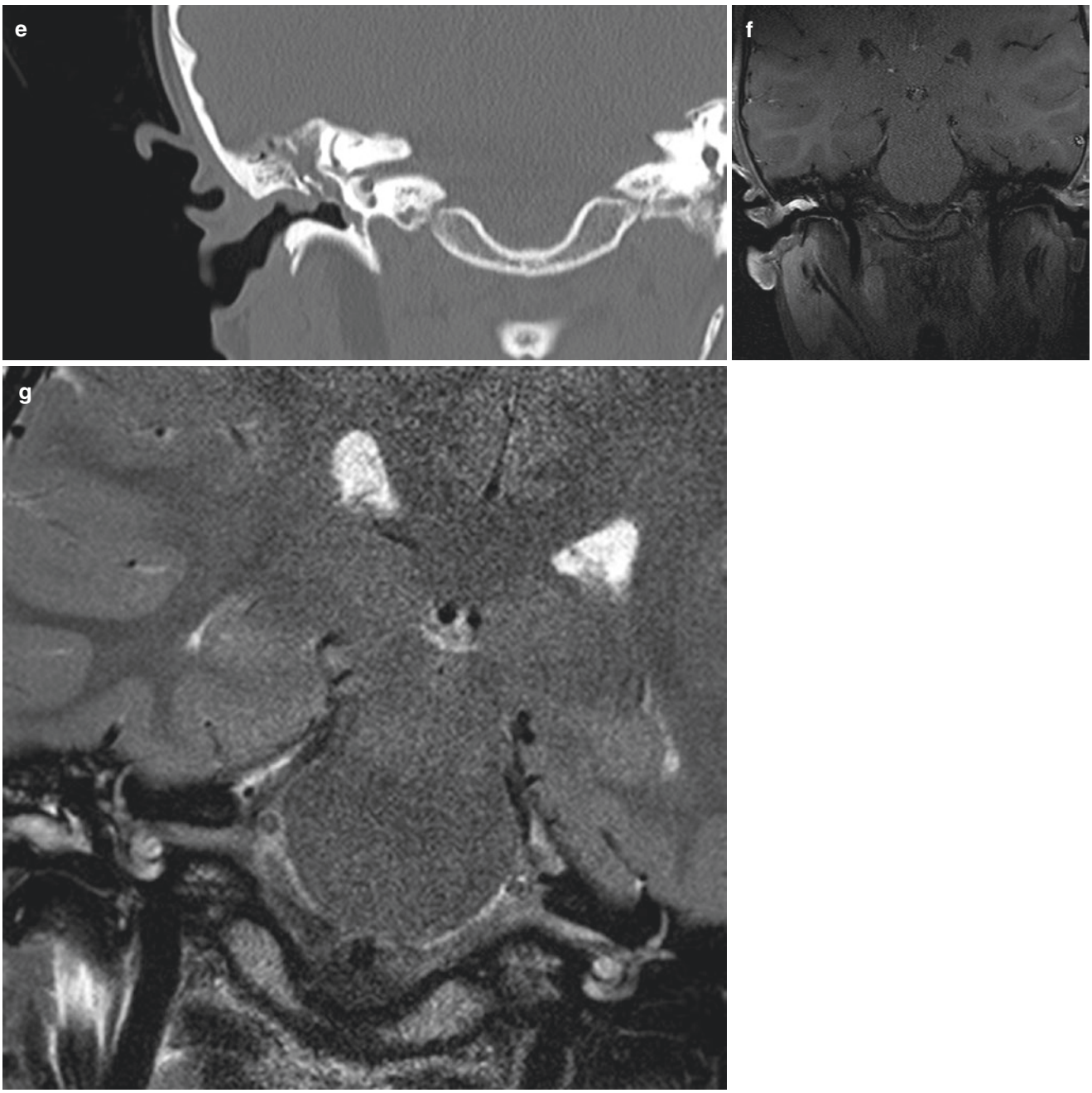


Fig. 4.3 (continued)

Radiological Features

High-resolution CT is recommended to delineate the extent of the lesion and evaluate the differential diagnosis (Fig. 4.3e).

A soft tissue density lesion will be seen with or without bone erosion. Some hemangiomas contain spicules of bone which can be visible on CT [33]. A contrast-enhanced scan would provide additional information that may be of value in certain circumstances (e.g., to determine extent in the pres-

ence of middle ear effusion, concern for other vascular anomalies). MRI is more likely to reveal small lesions within the internal auditory meatus as have been found in adults. A high-intensity signal is seen on T2 imaging, moderate signal on TI, and enhancement seen with gadolinium (Figs. 4.3f and 4.3g).

Management

Complete surgical excision is the recommended treatment [26, 28], following the principle familiar to pediatric cholesteatoma surgery of conserving functions of the ear when it is possible to do so without compromising the resection.

Glomus Tumor

Definition

Glomus tumors are paragangliomas that are thought to arise from glomus bodies, sub-millimeter aggregates of neural crest cell derivatives that are histologically similar to the carotid body [34]. Glomus bodies are found along the course of parasympathetic nerves in the middle ear cleft (Jacobson's nerve which is the tympanic segment of the glossopharyngeal nerve and Alderman's or Arnold's nerve, the aural segment of the vagus nerve) and also in adventitia of the jugular bulb. An early distinction was made between these two sites of origin into glomus tympanicum and glomus jugulare [35]. These terms are still in use, but more recent classifications provide more surgically useful categories (Table 4.1) [36, 37]. Other nomenclature has also been used including the terms chemodectoma and non-chromaffin paraganglioma. They are locally invasive and destructive tumors which are only rarely malignant.

Table 4.1 Classifications of glomus tumors of the temporal bone [36, 37]

Fisch		Glasscock-Jackson
Type A	Limited to promontory of middle ear	Type I
	Confined to middle ear (glomus tympanicum)	Type II
Type B	Tympanomastoid location, no infra-labyrinthine extension	Type III
	Tympanomastoid location with external ear canal extension	Type IV
Type C	Tympanomastoid location, with infra-labyrinthine extension	
Type D	Intracranial extension	

Glomus tumors are hardly even seen in children, occurring seemingly many hundred times less commonly than in adults [38]. A review of ten cases was published in 1988 [38] and only sporadic cases have been reported since [39–41]. There appears to be no gender predilection, unlike the female preponderance seen in adults. Mitochondrial succinate dehydrogenase (SDH) gene mutations predispose to neural crest cell tumors and it is possible that this could cause glomus tumors in young people [42].

Clinical Presentation

The commonest age of presentation has been noted as 10–13 years, but reports of cases in infancy show that much younger tumor development occurs [38, 41, 43]. Children old enough to describe symptoms may present with tinnitus, which is classically but not invariably pulsatile, and hearing loss. Facial and other cranial nerve weakness, including bulbar palsy, may be the presenting feature [44]. Bloody otorrhea from polypoid erosion of the ear canal can also occur [43]. A dull red mass under the tympanic membrane, classically looking like the "rising sun," is a more likely appearance on otoscopy. Pulsation may be visible and can be recorded on tympanometry [45]. Uncommonly, glomus tumors secrete catecholamines, so some children have hypertension at presentation [38]. In adults secretion is thought to be more likely from a coexistent phaeochromocytoma [46]. Metastatic spread to lungs, bones, and brain has been reported from a glomus tumor in childhood [47].

Differential Diagnosis

The rarity of glomus tumors in children means that the diagnosis is unlikely to be anticipated. The classic otoscopic appearance may be obscured by the presence of concomitant otitis media with effusion or even confused with acute otitis media [38, 39]. The presence of vascular tissue in the middle ear space may be mistaken for granulation tissue intraoperatively [38]. Aberrant carotid artery within the middle space has been reported as having similar appearance on otoscopy but can be readily distinguished by CT imaging [48, 49] (Figs. 4.3c and 4.3d). The appearance should not be confused with a high jugular bulb which has a blue coloration (Figs. 4.4a and 4.4b).

Other reported conditions in the differential diagnosis include encephalocele (Figs. 4.4c and 4.4d) and other tumors including endolymphatic sac tumor [46].

Radiological Features

CT scan reveals a soft tissue mass that enhances with intravenous contrast. Bone erosion is seen in all but the smallest lesions (Fig. 4.4e).

Erosion of the spike of bone between the internal carotid artery and jugular bulb is an early feature of a hypotympanic tumor.

A "salt and pepper" pattern describes the black and white speckling seen on MRI from areas with high vascular flow causing a signal void and vascular stasis causing high-intensity signal [50] (Fig. 4.4f).

Feeding vessels can be revealed by angiography (Fig. 4.4g).

Management

24-hour collection of urine for measurement of vanillylmandelic acid (VMA) levels is recommended to predict the risk

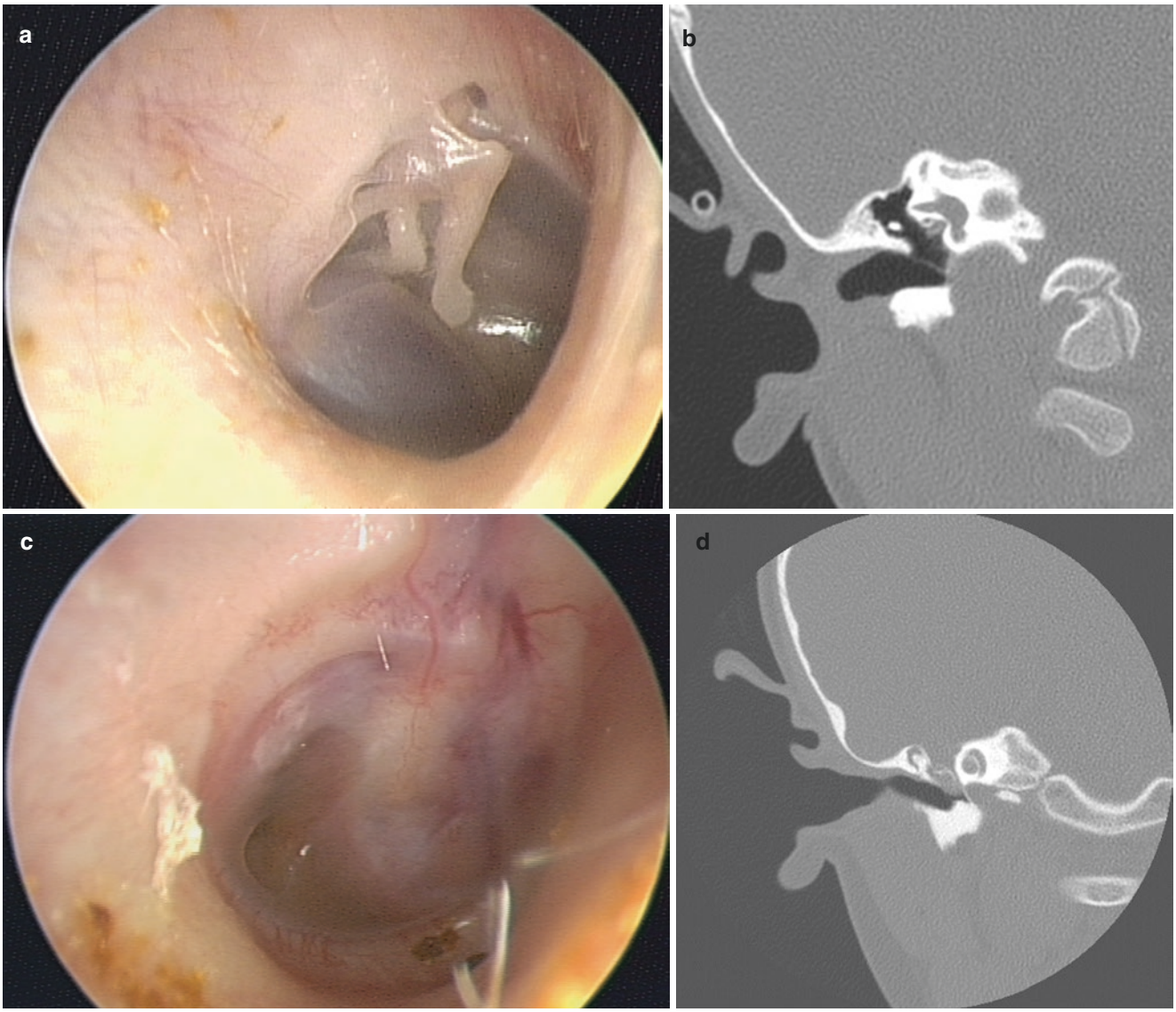


Fig. 4.4 (**a**) Otoscopy demonstrates bluish color of inferior mesotympanum consistent with a high jugular bulb. (**b**) Coronal CT of right ear showing a high jugular bulb. (**c**) Otoscopy of right ear showing pinkish mass behind tympanic membrane found to be an encephalocele. (**d**) Coronal CT of encephalocele of right ear showing dehiscence of bony tegmen with soft tissue mass in the middle ear. This was visible on otoscopic exam (Fig. 4.4c). (**e**) Axial CT of glomus tumor showing mass in middle ear, bulging of tympanic membrane, displacement of ossicles, and slight erosion of bone. (**f**) Axial MRI of glomus tumor showing "salt and pepper" pattern from areas with high vascular flow causing a signal void and vascular stasis causing high-intensity signal. (**g**) Angiography in patient with glomus tumor helps outline vascularity for preoperative planning

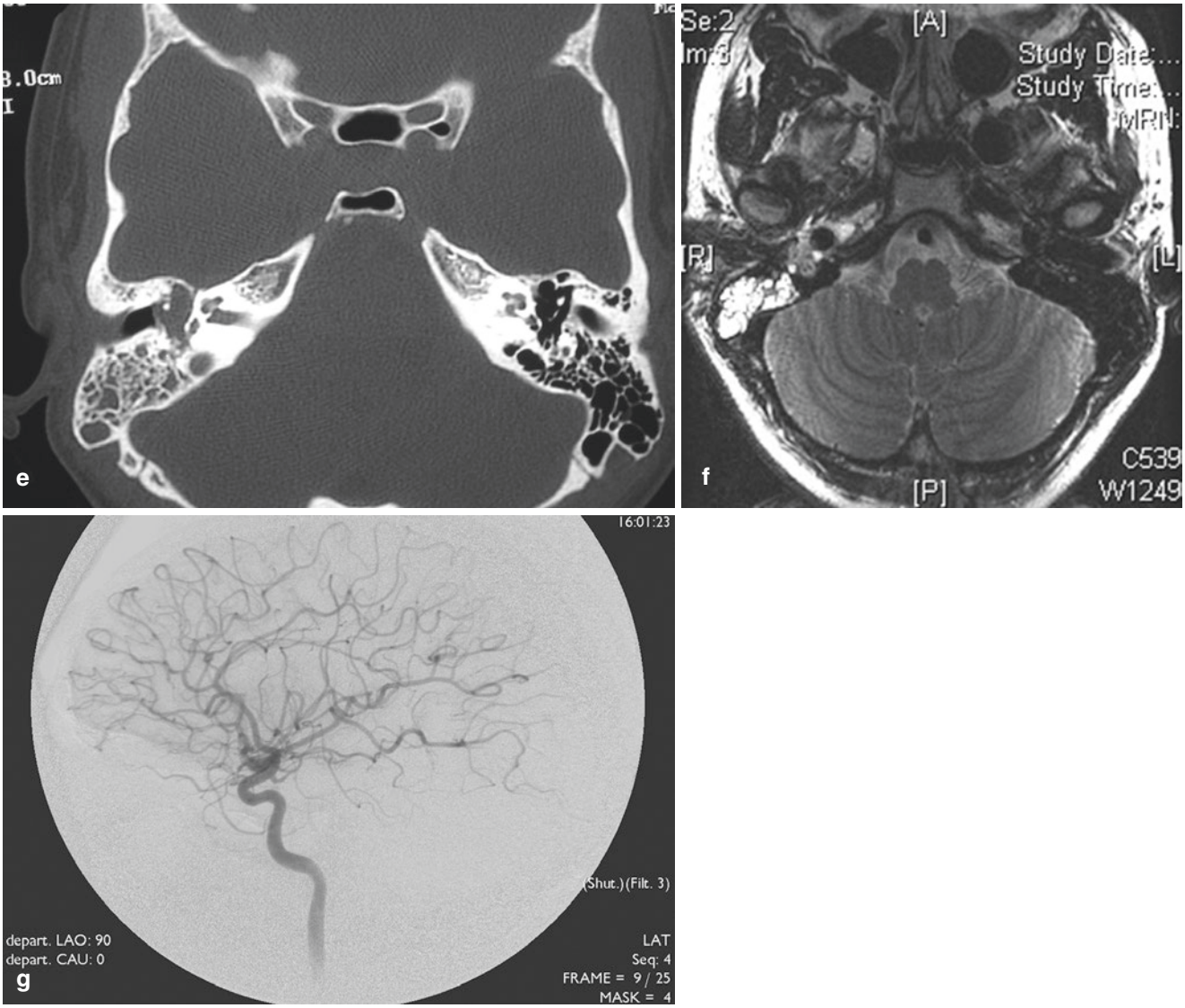


Fig. 4.4 (continued)

of hypotensive collapse associated with removal of a secretory tumor. Imaging with contrast-enhanced high-resolution CT of the temporal bone (+/− neck) is necessary to determine the extent of the lesion and screen for a contralateral lesion. Additionally, MRI may be of value to delineate soft tissue boundaries, for example, dural involvement. The radiological features can be sufficiently diagnostic that biopsy may not be necessary, but because of the rarity of the pathology in children, intra-operative histopathology with frozen section may be advisable. Testing for germline mutations (i.e., SDH) has been recommended to guide surveillance for other neural crest tumors [42, 46].

A conservative policy of observation and serial imaging, recommended in slow-growing tumors of the elderly, would seem inappropriate for pediatric cases. When possible, complete surgical excision is the treatment of choice. Preoperative embolization can be used to reduce intraoperative hemorrhage, though is not considered necessary by all surgeons. Glomus tympanicum can be cured by removal through the external ear canal; a totally endoscopic approach has been

used in adults [51] and doubtless is feasible for appropriately selected pediatric cases. Fisch type B tumors can be removed with a combined approach intact canal wall tympanomastoidectomy. As described more commonly in adults, more extensive tumors may require a hypotympanotomy, transmastoid retrofacial approach, or lateral infratemporal fossa approach with control of the facial nerve, carotid sheath contents in the neck [46, 52, 53]. Intracranial extension requires craniotomy and neurosurgical involvement. In adults, it has been thought preferable to leave small quantities of tumor adherent to facial nerve, carotid, or labyrinthine in order to minimize morbidity [46]. For lesions that exceed the limits of complete surgical excision, radiotherapy can be considered to halt tumor growth, though is otherwise avoided.

Cholesterol Granuloma

Definition

Cholesterol granuloma is a collection of thick brown liquid that occupies what would otherwise, in the healthy ear, be air spaces within the pneumatized tympanomastoid bone. It may be associated with areas of chronic granulation tissue, but despite its name, cholesterol granuloma is predominantly acellular. The fluid contains crystals of cholesterol which are probably breakdown products of hemoglobin or marrow. It may be confined to the petrous apex or fill other tympanomastoid spaces. It can arise spontaneously, with chronic suppurative otitis media or after tympanomastoid surgery [54].

Clinical Presentation

Cholesterol granuloma is occasionally seen in children, but reported series indicate that it more commonly presents in adulthood [55]. It is typically unilateral. The clinical features of cholesterol granuloma depend upon its location.

When filling the middle ear space it causes persistent painless conductive hearing loss, just like otitis media with effusion (OME). The otoscopic appearance of a dark colored fluid under the tympanic membrane is unmistakably different from OME. Although at the time of drainage, the fluid is dark brown with a yellowish tint, it may appear more blue-black when seen through the eardrum (Fig. 4.5a).

When present in the mastoid alone, it is typically asymptomatic, and may be encountered at the second stage of tympanomastoid surgery for cholesteatoma. This is more likely after canal wall up surgery, but cholesterol granuloma can form underneath the cutaneous lining of a modified radical mastoidectomy cavity (Fig. 4.5b).

Cholesterol granuloma of the petrous apex in childhood may also be asymptomatic and present as an incidental finding on diagnostic imaging for an unrelated reason (Fig. 4.5c).

Trapped within the apex of the petrous bone, cholesterol granuloma may expand and cause bone erosion, though at least in adults it appears that most change little over a period of a few years [55]. Expanding lesions may go on to compress the facial nerve and cause facial weakness, pain, or paresthesia. Reports of adult series note that headache is not relieved by surgical drainage, hinting perhaps that petrous apex granuloma may not have been the cause of the headache [55].

Differential Diagnosis

The appearance of a dark effusion under a normal tympanic membrane could be mistaken for hemotympanum. A recent history of trauma sufficient to cause temporal bone fracture would make hemotympanum the more likely diagnosis. When not visible on otoscopy, the diagnosis and differential is brought up with temporal bone imaging. The characteristic MRI features of cholesterol granuloma are fairly unmistakable though a mucocele can appear similar. CT findings are much less specific, and the differential diagnosis includes almost any non-enhancing soft tissue space-occupying material that may or not be associated with bone erosion from otitis media with effusion to expansile soft tissue mass.

Radiological Features

The reliable finding of cholesterol granuloma on MRI imaging is hyperintensity with both T1 and T2 sequences (Figs. 4.5d and 4.5e).

Thinned bone around the periphery may give a low intensity signal [55]. The signal remains high with fat suppression. There is no restriction of diffusion-weighted imaging. The contents do not enhance with gadolinium.

CT shows a non-enhancing soft tissue density lesion. Central bony septations may (or may not) be eroded, as may bone around the periphery from expansion [55]. As a result dehiscence of adjacent structures may be seen (Fig. 4.5c).

Management

A tympanostomy tube can be placed to ventilate the middle ear and alleviate conductive hearing loss. Although the ear may become healthy with the tube in situ, without otorrhea, recurrence can occur following extrusion of the tube [56].

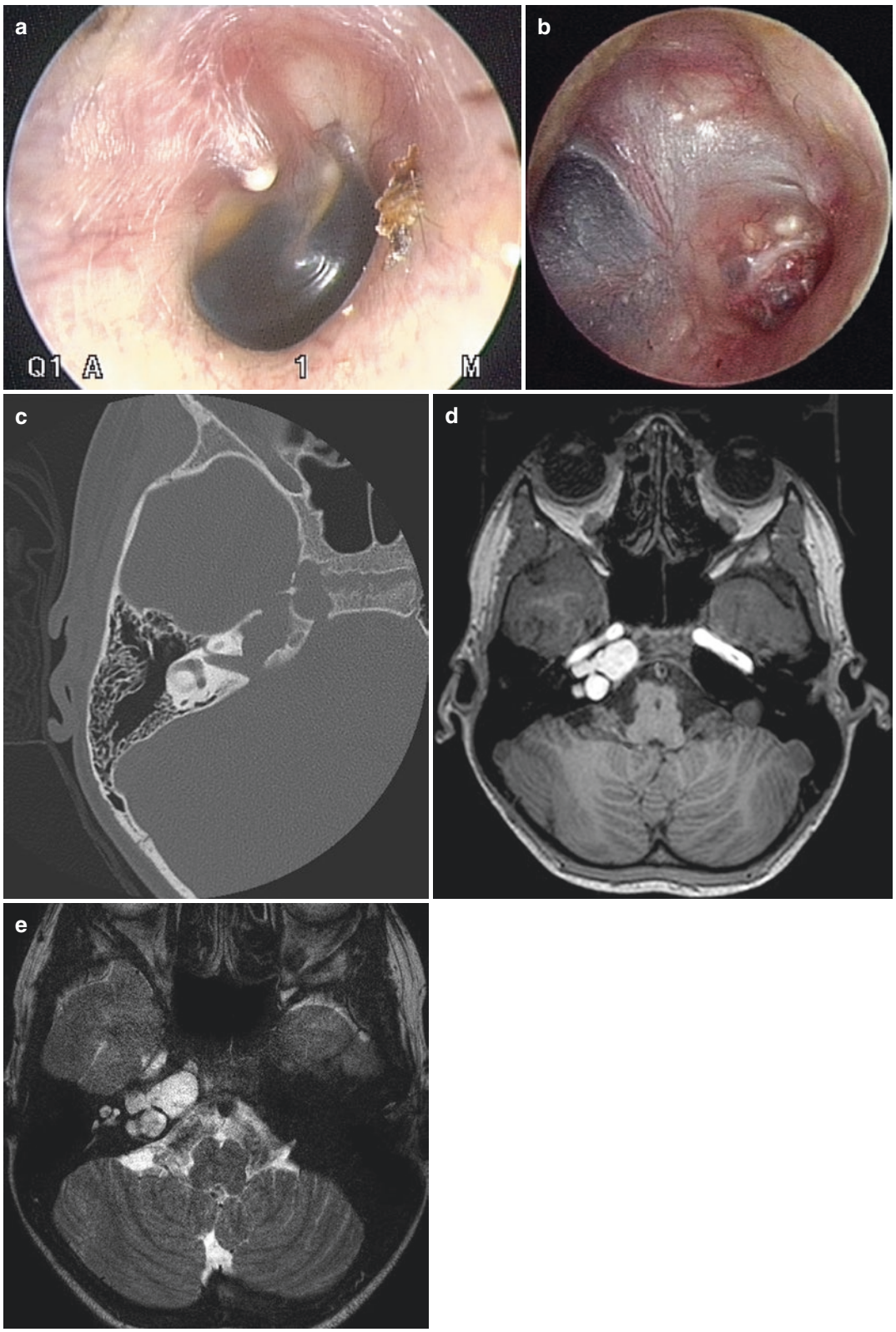


Fig. 4.5 (**a**) Otoscopic exam of right ear in patient with cholesterol granuloma reveals a blue-black coloration when seen through the eardrum even though at the time of drainage, the fluid is dark brown with a yellowish tint. Coincidently noted is a small "whitish" epidermal inclusion cyst of the tympanic membrane. (**b**) Cholesterol granuloma of the right mastoid formed underneath the cutaneous lining of a modified radical mastoidectomy cavity seen as a blue-black coloration. (**c**) Axial CT showing lytic lesion consistent with a cholesterol granuloma of the petrous apex. These lesions are usually asymptomatic in childhood and may present as an incidental finding on diagnostic imaging being done for an unrelated reason. (**d**) Axial T1 MRI imaging of cholesterol granuloma of petrous apex showing hyperintensity. (**e**) Axial T2 MRI imaging of cholesterol granuloma of petrous apex showing hyperintensity

Conservative management is recommended for asymptomatic cholesterol granuloma. This may take the form of clinical observation, or repeated MRI to determine whether the lesion is expanding [57]. When neurologic compromise occurs or appears at risk from expansion of the lesion, surgical drainage can be considered. The trans-sphenoidal route to the petrous apex is widely utilized in adults, but in younger children access is more challenging. The sphenoid sinus is small, and access impeded by marrow of the basisphenoid. An infracochlear approach may be preferable but recurrence may occur if the surgical drainage pathway into the middle ear does not remain open [58].

Langerhans Cell Histiocytosis

Definition

Langerhans cell histiocytosis (LCH) is characterized by the nonmalignant proliferation of Langerhans cells [59]. These are dendritic histiocytes characterized histologically by the presence of Birbeck granules. LCH is now the preferred, and all-encompassing, term which replaces previous nomenclature including: histiocytosis X, eosinophilic granuloma, Letterer-Siwe disease, Hand-Schuller-Christian syndrome, Hashimoto Pritzker syndrome, self-healing histiocytosis, pure cutaneous histiocytosis, Langerhans cell granulomatosis, Langerhans cell (eosinophilic) granulomatosis, type II histiocytosis, and non-lipid reticuloendotheliosis [60]. LCH can be distinguished from other disorders of histiocytes which comprise macrophages and other types of dendritic cell, including hemophagocytic syndromes, Rosai Dorfman disease, and some malignant sarcomas [60, 61].

LCH is a fairly rare disorder found predominantly in childhood. Although it can involve many organs, it most commonly involves bone, and often the skull. LCH may be isolated and found in a single bone such as the temporal bone (monostotic disease) or also be found in other bones in which case it is referred to as single system disease. Involvement of one or more other organs, such as skin, lungs, or lymph nodes, is categorized as multisystem disease [62]. LCH involvement of the temporal bone has been reported in mono-ostotic, single system, including bilateral temporal bone foci, and multisystem disease.

Clinical Presentation

Temporal bone LCH causes otalgia, often with swelling around the ear. Otorrhea may occur following skin breakdown over the lesion within the ear canal. Cranial nerve palsy and labyrinthine deficits are uncommon but can occur [63]. Systemic features of LCH include skin rashes, otorrhea, fever, loss of appetite, diarrhea, poor weight gain, growth failure, polydipsia, polyuria, respiratory symptoms, irritability, behavioral, and neurological changes [62]. Otorrhea after successful treatment has occurred from secondary cholesteatoma growing in through an ear canal wall defect caused by temporal bone LCH [64].

Differential Diagnosis

Chronic otitis media, mastoiditis, cholesteatoma, and sarcoma have been listed as the principal disorders in the differential diagnosis of LCH in the temporal bone [62]. Of these, LCH is most commonly misidentified as acute mastoiditis [63, 65]. Ewing sarcoma, osteogenic sarcoma, lymphoma, aneurysmal bone cyst, and juvenile xanthogranuloma should also be considered in the differential diagnosis [62].

Radiological Features

LCH produces lytic lesions of bone with sharply demarcated edges that are clearly seen with CT imaging (Fig. 4.6a) [65].

Bone erosion may be extensive and extend into the labyrinth. It typically involves the mastoid more than the petrous apex [63, 66]. The lesion commonly extends into adjacent soft tissue, either intra or extracranially (Fig. 4.6b) [63]. Enhancement is seen with intravenous contrast.

On MRI, LCH lesions are bright on T2-weighted images and of variable brightness with T1. Enhancement is seen with gadolinium [63].

Management

Biopsy is required to establish the diagnosis. Evaluation for other foci of disease is then required, including a skeletal survey, chest X-ray, and imaging of the abdomen [62]. Monostotic LCH may involute spontaneously, especially after biopsy and curettage, but when temporal bone disease extends into adjacent soft tissue, systemic therapy has been recommended [62]. Multifocal single system disease (i.e., in other bones as well as the temporal bone) has a higher tendency to relapse so systemic therapy is advised, for example, with steroids and vinblastine [62]. A more prolonged course of this treatment and second-line treatment are required for multisystem or refractory disease as the prognosis is less favorable [62]. Radiotherapy is not widely utilized. Follow-up beyond puberty and for at least 5-years after treatment is recommended.

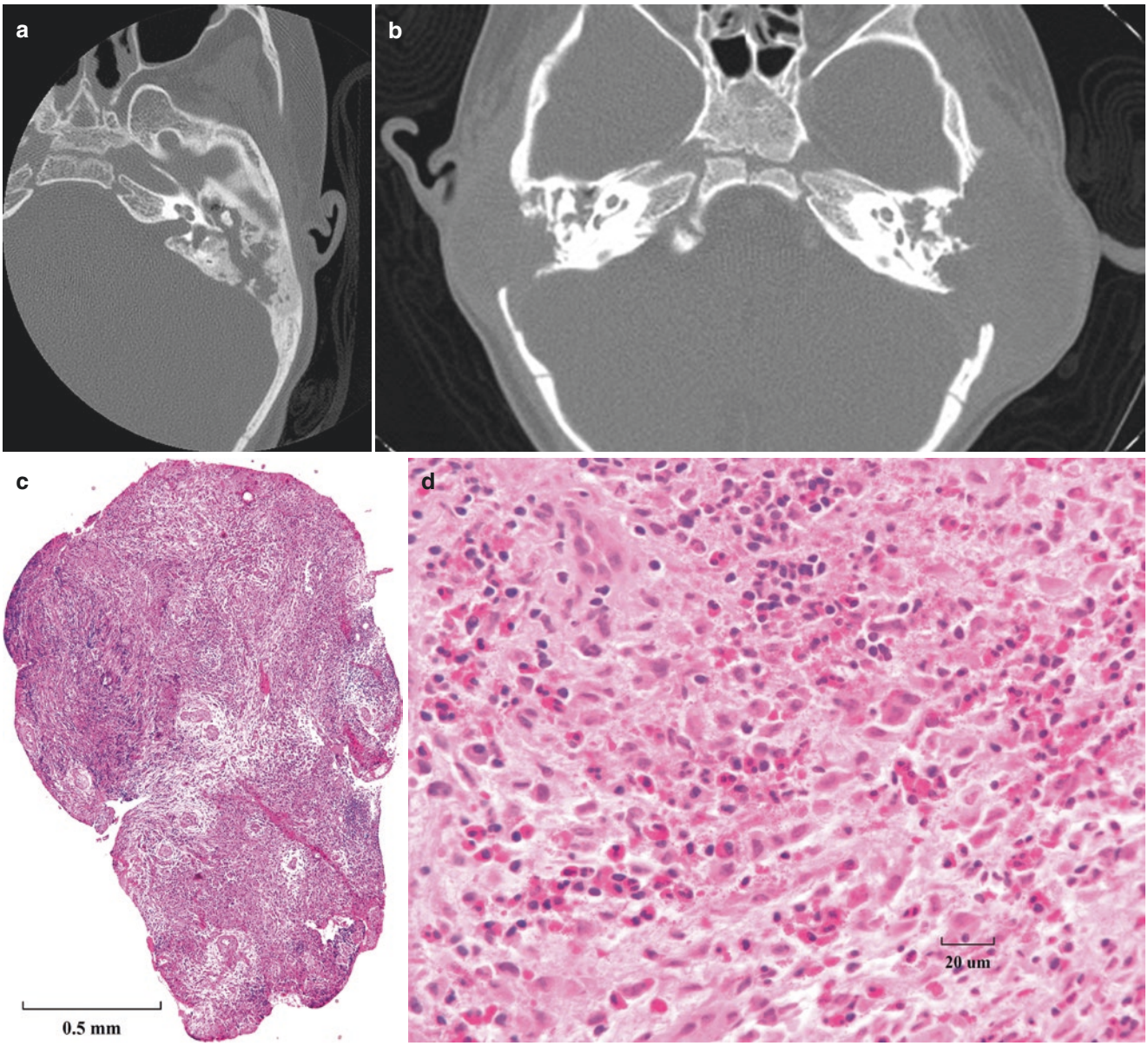


Fig. 4.6 (**a**) Axial CT of child with LCH producing lytic lesions of bone with sharply demarcated edges. (**b**) Axial CT of child with LCH producing lytic lesions of both temporal bones with sharply demarcated edges. (**c**) H&E stained frozen section shows fibro-granulation like tissue with a pseudo-mixed chronic inflammatory infiltrate with histiocytes and eosinophils. (**d**) H&E stained formalin-fixed, paraffin-embedded section shows prominent foci of eosinophils among a population of histiocytes of various sizes. (**e**) H&E stained formalin-fixed paraffin-embedded section reveals abnormal cytological details of these histiocytes. They contain coffee bean-shaped nuclei with nuclear folds or longitudinal nuclear grooves. Their cytoplasm is eosinophilic and has a ground glass to fine granular appearance without inclusions of phagocytic vacuoles. (**f**) Immunostain shows these histiocytes are positive for S100. (**g**) Immunostain shows these histiocytes are positive for CD1a. (**h**) Electron microscopy shows each histiocyte has a crescent-shaped nucleus displaced to one side of the cell. The cytoplasm contains granular inclusion bodies, dilated cisternae of endoplasmic reticulum, some mitochondria, lysosome bodies, and micro vacuoles. (**i**). Electron microscopy at higher magnification shows the presence of diagnostic cytoplasmic inclusion bodies of a Langerhans cell (histiocyte). The inclusion bodies have zipper-like appearance: the Birbeck granule where the Langerin protein resides. (**j**) Follow-up axial CT of patient showing excellent response to treatment. (Pretreatment axial CT shown in Fig. 4.6a)

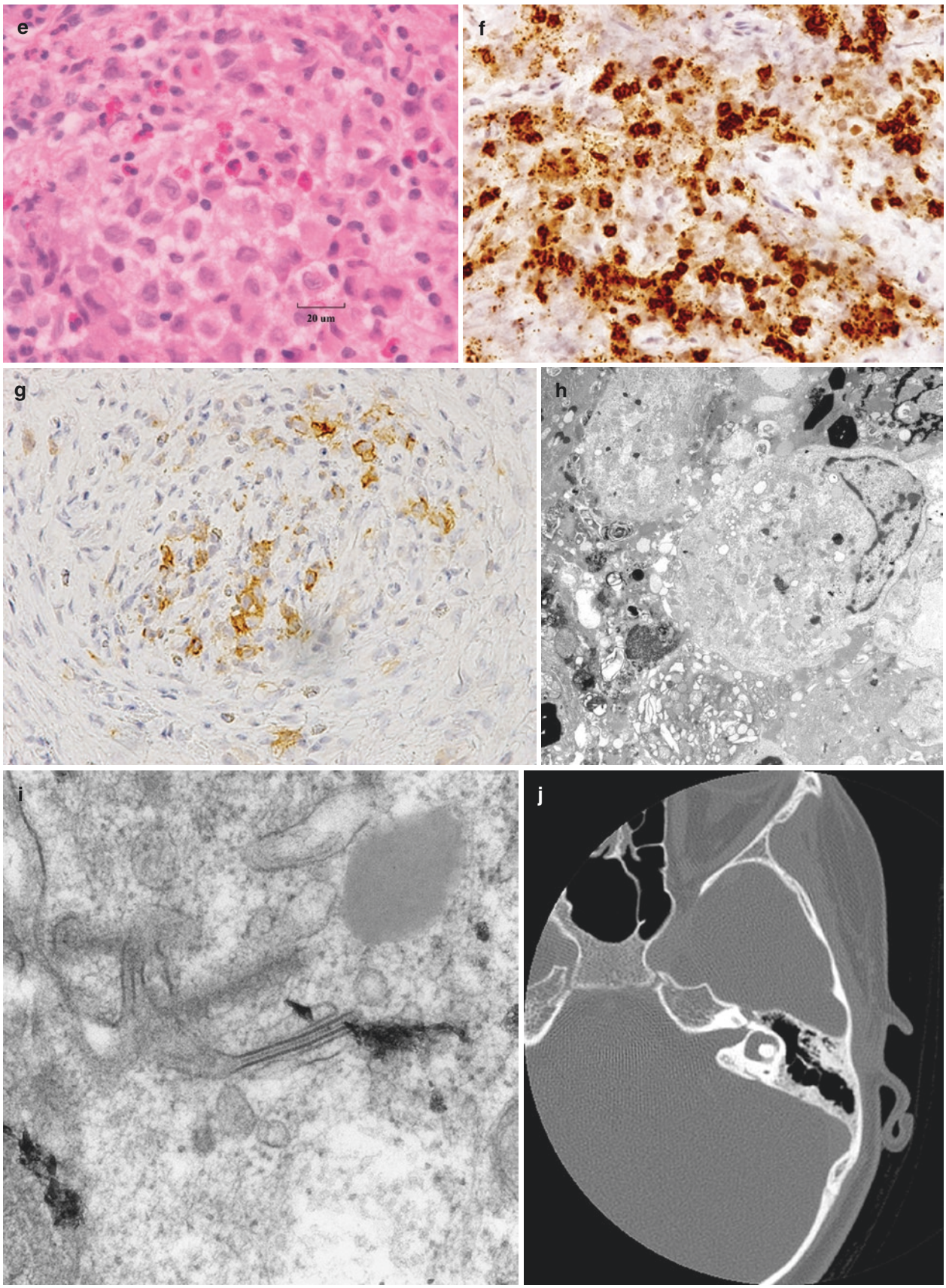


Fig. 4.6 (continued)

Clinical Example

In 2002, a 5-year-old girl presented with a 4-day history of feeling dizzy. This had come on suddenly in the evening. There was no vomiting or ataxia. An audiogram showed a bilateral hearing loss. Examination showed normal tympanic membranes. Imaging included both CT and MRI. Axial CT at presentation is shown in Fig. 4.6a.

The child had a combined approach tympanomastoidectomy, also known as a canal wall up tympanomastoidectomy, in January 2002. Fibrous tissue and granulation tissue were found intra-operatively (surgeon's not pathologist's observation!).

Histopathology showed moderate pseudo granulomas and palisading histiocytes with CD1A positive staining and EM Birbeck granules in the cytoplasm (Figs. 4.6c–4.6i).

Systemic workup included bone marrow biopsy, CT chest and abdomen, MRI of brain and pituitary to screen for DI risk. Multisystem disease was found including her lungs and kidney.

Treatment included prednisone and vinblastine and 6 mercaptopurine. Her progress monitored with MRI head and CT chest with an excellent response (Fig. 4.6j).

She had been remained free of disease until age 18 when her care was transferred to the adult oncologists.

Endolymphatic Sac Tumors

Definition

Heffner was the first to recognize that papillary-cystic adenocarcinoma of the temporal bone arises from the endolymphatic sac [67]. This rare tumor was then noted to be commonly associated with Von Hippel-Lindau (VHL) disease [68]. VHL is a dominantly inherited multisystem cancer syndrome caused by mutation in the VHL tumor suppressor gene which maps to chromosome 3p25–26 [69, 70]. In addition to endolymphatic sac tumors (ELST), VHL predisposes to retinal and central nervous system hemangioblastomas, renal carcinoma, pheochromocytoma, pancreatic, and islet cell tumors [69]. De novo mutations may occur, as noted especially in Chinese populations [71], so screening in suspected cases is appropriate even without family history. ELST appears to be a less common manifestation of VHL in families from the Indian subcontinent [72].

Presentation

ELST has been identified across an even age range from childhood throughout adulthood, being reported as in children as young as 4 years of age [67, 73]. There is an equal gender predilection. Tumors are usually unilateral, though bilateral cases are reported in VHL [70, 74]. Unless detected while asymptomatic, as may occur when screening individuals with VHL, ESLT presents with auditory symptoms including sensorineural hearing loss, tinnitus, aural fullness, and disequilibrium of balance [75]. Hearing loss is typically severe to profound at presentation and may be of sudden onset [70]. Of note, a sensation of aural fullness or imbalance is more common in patients with VHL that have no evidence of ESLT on imaging when compared with family members without VHL [70]. It is not known if this represents a preclinical disease state. More extensive lesions present with facial weakness, a red mass behind the eardrum or even polypoid growth into the external auditory meatus [67, 74].

Differential Diagnosis

Other tumors that may grow in proximity to the endolymphatic sac, at least in adults, include schwannomas, meningiomas, epidermoid cysts, and rare malignant tumors such as small-cell sarcoma, squamous cell carcinoma, malignant meningioma, atypical rhabdoid-teratoid tumor, and malignant ganglioglioma [76]. Association of ELST with aneurysmal bone cyst has been reported [77].

Radiological Features

ELST is seen on CT imaging as a bone-eroding mass extending into the posterior fossa which may be centered anatomically on the position of the endolymphatic sac. Spicules of calcification within the mass and a thin rim of bone around the posterior surface are often present [78]. MRI shows heterogeneous signal intensity with T1 and T2 sequences. Contrast enhancement and flow voids are representative of the high vascularity of ELST [77].

Management

When feasible, total resection is recommended to reduce the risk of disease recurrence, with more favorable outcome expected from smaller lesions [75, 79, 80]. Screening for the tumor in VHL is thus strongly recommended. Preoperative embolization has been recommended for sporadic ELST (i.e., without VHL) as such tumors tend to be detected when larger and may bleed profusely [81]. Stereotactic radiotherapy has also been used for tumor control in non-operable disease [79].

Clinical Example

A 7-year-old female presented with a painless mass behind her right ear present for over 1 year. Imaging with CT and MRI showed 5 × 5 × 5 cm mass in posterior fossa with lytic destruction of petrous temporal bone, as well as C1 with encasement of vertebral artery and obstructed flow of jugular and sigmoid sinus. Images are shown in Figs. 4.7a–4.7d.

Biopsy revealed low-grade papillary adenocarcinoma of endolymphatic sac origin. Histology is shown in Figs. 4.7e–4.7k.

The patient failed chemoradiation and died at age 12.

Lymphoma

Definition

Lymphomas are tumors of lymphocytes that predominantly develop in lymph nodes. The World Health Organization proposed a revised classification of the many different types of lymphoma in 2016, which can be broadly categorized into Hodgkin's lymphoma, mature B-cell neoplasms, and mature T-cell (and natural killer cell) neoplasms [82]. Posttransplantation lymphoproliferative disorder and histiocytosis are two further subgroups within that classification of lymphoid disease.

Extranodal lymphoma is of the non-Hodgkin's type, arising in the head and neck most commonly in other lymphoid tissue such as in Waldeyer's ring. The temporal bone is an unusual site for primary lymphoma, one review finding only ten recorded cases [83]. Metastasis of lymphoma to the temporal bone has also been reported rarely [84]. Previous reports of primary lesions in the temporal bone in young children have been of B-cell lymphoma [83, 85, 86]. Mucosa-associated lymphoid tissue (MALT) can be found in the middle ear and Eustachian tube of children especially those with a history of otitis media, which, one might speculate, provides the potential for lymphoma development in the temporal bone [87, 88]. MALT is known to cause extranodal B-cell lymphoma, most commonly in the stomach. T-cell temporal bone lymphoma can also occur in childhood (see case below).

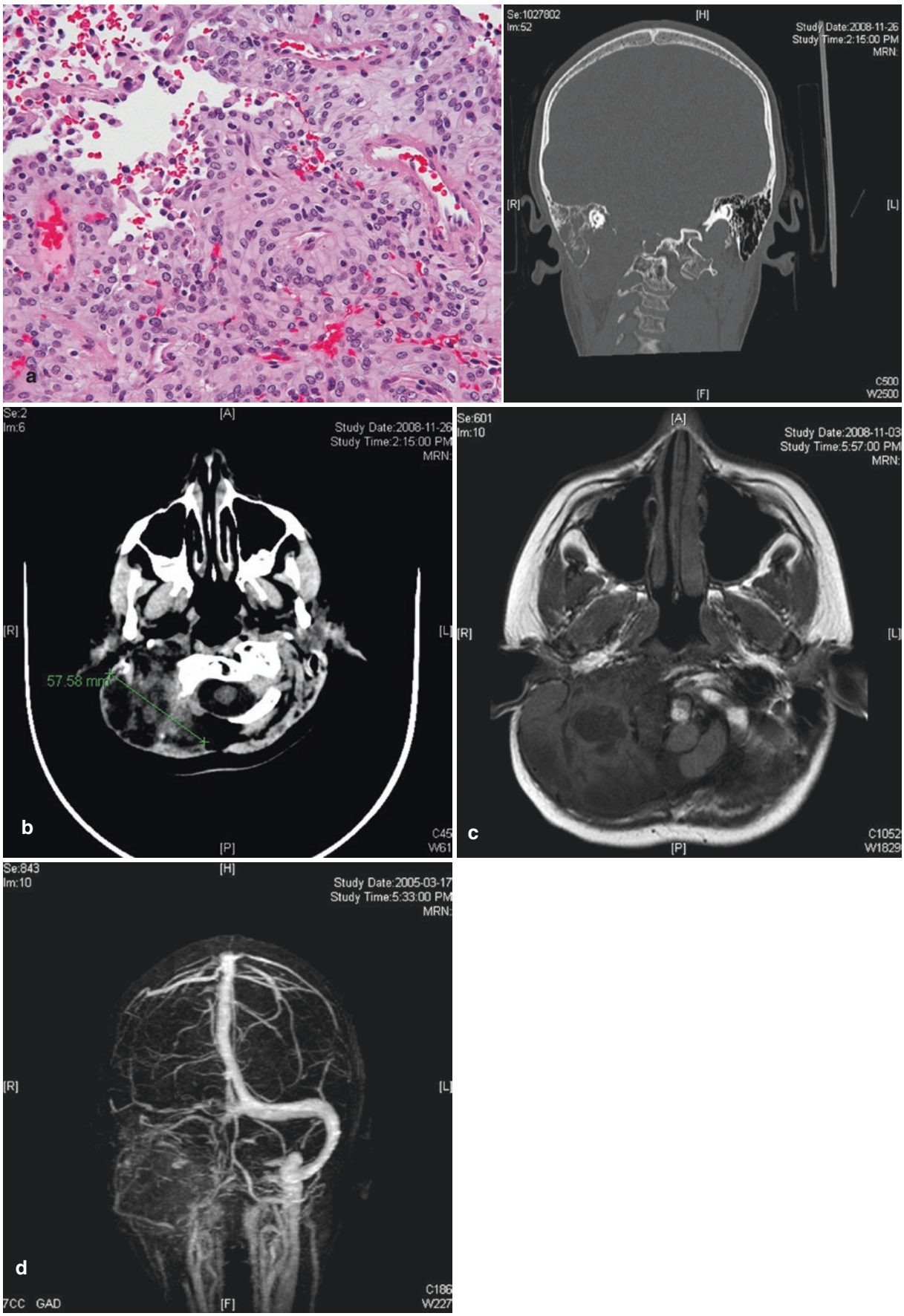
Clinical Presentation

Temporal bone lymphoma has been reported in children as young as 2 years of age. Presenting features reported for temporal bone disease in children include otalgia, conductive hearing loss, facial paralysis, and low-grade fever [83, 85, 86]. Presentation with pain, postauricular swelling, and fever may appear similar to acute mastoiditis. Two reported cases of temporal bone lymphoma in infancy were positive for Epstein–Barr virus markers [85, 86]. One of these cases resolved after surgical biopsy without additional treatment [85].

Differential Diagnosis

Other more common temporal bone neoplasms such as rhabdomyosarcoma and histiocytosis may be suspected. Necrotizing otitis media has been considered as an alternative diagnosis in an infant with lymphoma presenting with features of acute mastoiditis [86]. An illustrative example of necrotizing otitis media is shown in (Figs. 4.8a and 4.8b) for comparison.

Fig. 4.7 (**a**) Coronal CT showing large posterior fossa lesion with lytic destruction of petrous temporal bone, skull base as well as C1. (**b**) Axial CT showing lytic destruction of skull base and C1 with encasement of vertebral artery. (**c**) Axial MRI showing large posterior fossa lesion with lytic destruction of petrous temporal bone. (d) MRA with gadolinium showing large posterior fossa lesion encasing vertebral artery and obstructed flow of jugular and sigmoid sinus. (**e**) H&E section shows tumor has a solid, epithelial-like growth pattern. Papillary areas are better seen at the periphery. Cytogenetic analysis by G-banding and spectral karyotyping shows complex chromosomal alterations:45,X,der(X),der(3),der(3),ins(4;11)(q?21;??),der(11),der(11,22),der(18) [4]/46,XX [13]. (**f**) H&E shows collections sheet-like epithelial cells nested around the small blood vessels exhibit some polarity. The tumor nuclei are round to oval with mild variations in shape and sizes. They have condensed fine chromatin with infrequent small nucleoli. (**g**) EMA pan cytokeratin. Immunostains show focal pan cytokeratin (CK) and epithelial membrane antigen (EMA). Not shown are the positive stains for CK 7, CK 19, and low molecular weight cytokeratin. The tumor is negative for CK 20, CK 10, CK 8, and carcinoembryonic antigen. The tumor is also strongly and diffusely positive for vimentin and CD56. (**h**) Electron microscopy shows tumor cells have rich amounts of intermediate filaments within their cytoplasm and other cyto-organelles such as mitochondria are rare and endoplasmic reticulum, lysosomes, or other granules are absent. Their membrane surfaces have occasional desmosomes and complex interlacing membrane folds are present on parts of their surfaces. (**i**) Electron microscopy shows presence of microvilli on tumor cell surfaces (left side of this photomicrograph) as well as a possible invagination of secretory surfaces with microvilli into the cell cytoplasm. (**j**) A high power view of this structure is shown. (**k**) Electron microscopy shows three intracellular secretory-type inclusions within one of the tumor cells. Proteinaceous materials are seen within these inclusions together with microvilli. This ultrastructural feature is diagnostic of adenocarcinoma and is absent in other carcinomas such as squamous cell carcinoma in the head and neck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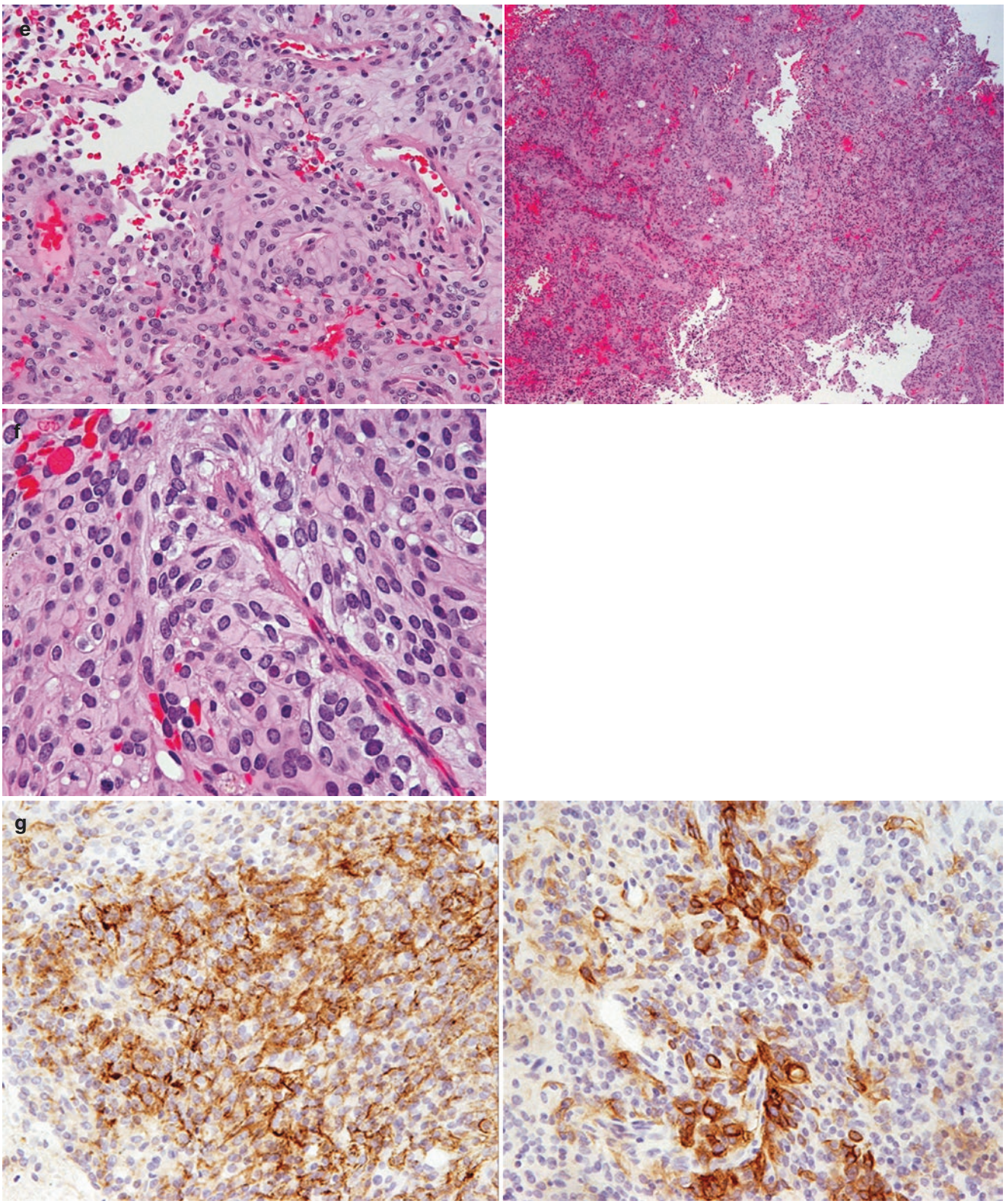

Fig. 4.7 (continued)

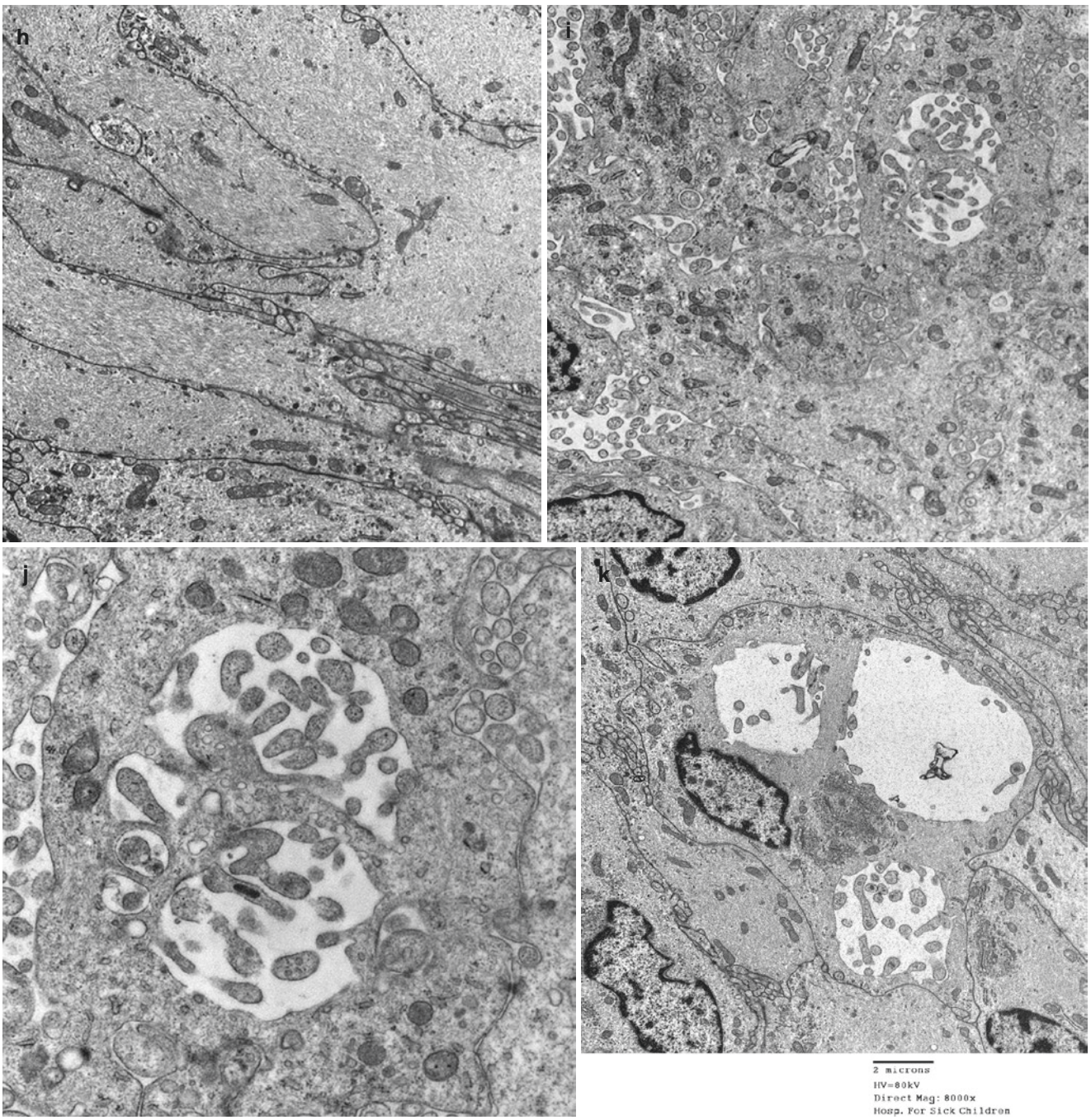

Fig. 4.7 (continued)

Radiological Features

CT and MRI findings may be fairly nonspecific, revealing a soft tissue density mass with bone erosion (Fig. 4.8c).

Management

The diagnosis is unlikely to be suspected from clinical features alone. Surgical biopsy is needed to make the diagnosis, with some histopathologists preferring fresh tissue specimens, that is, without formalin, for optimum immunohistochemical staining. Temporal bone imaging with CT +/− MRI can be used to guide the surgical approach, either through the ear canal or mastoid. Further care involves hematology–oncology services for staging and treatment. Screening for lymphoma at other sites may include sectional imaging of neck, thorax and abdomen, bone marrow aspiration biopsy, and cerebrospinal fluid analysis. Treatment is likely to be with chemotherapy based upon lymphoma subtype and current treatment guidelines.

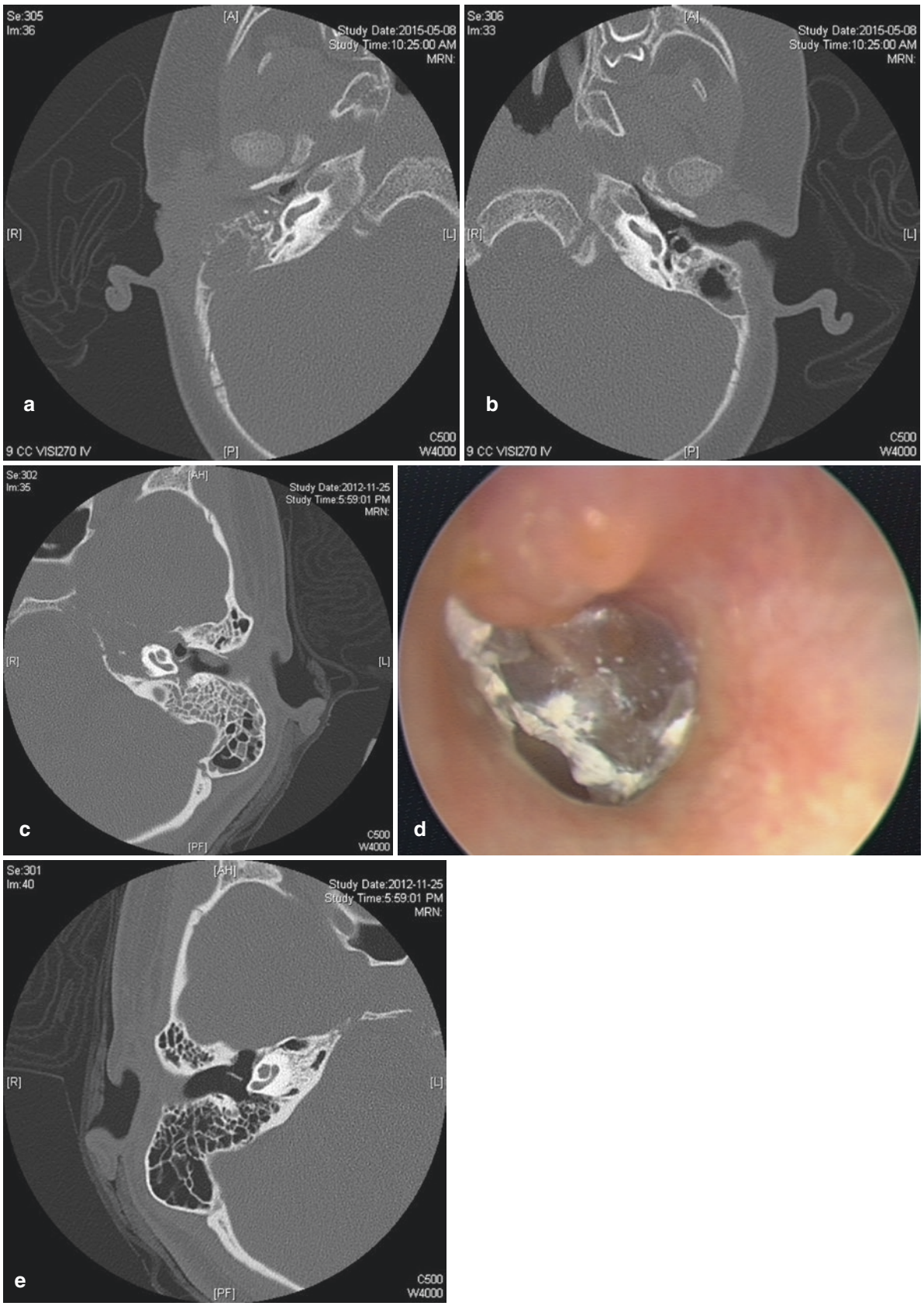

Fig. 4.8 (**a**) Axial CT of a child with necrotizing otitis media of the right temporal bone showing destructive changes of bone that may not be distinguishable from other benign or malignant conditions. The left ear is shown for comparison in Fig. 4.8b. (**b**) Axial CT of left ear of child with necrotizing otitis media of the right ear is shown for comparison. (**c**) Axial CT showing a nonspecific soft tissue mass in the temporal bone with bone erosion of the petrous apex. Note the mass extends to the ear canal and was visible on otoscopy (Fig. 4.8d). (**d**) Otoscopy of the left ear showing a soft tissue mass of the superior/medial external ear canal. (**e**) Axial CT of right side reveals no abnormalities

Clinical Examples

Case 1

A 15-year-old girl presented with diplopia from a left VI nerve palsy 2 weeks after a left facial nerve palsy had been labeled as Bell's palsy. She had a previous 1 month history of left-sided headache then otalgia. Other symptoms included hearing loss, decreased sensation of taste, anorexia, and nausea but no fever or sweats. A soft tissue swelling was noted in the left ear canal (Fig. 4.8d) and also shown on axial CT (Fig. 4.8c).

The canal lesion was biopsied and she was diagnosed with T-cell lymphoma involving the petrous apex as well (Fig. 4.8c). No disease was seen in the mesotympanum nor in the contralateral temporal bone (Fig. 4.8e).

The tumor was unresponsive to chemotherapy then radiotherapy. It expanded rapidly into the sphenoid sinus where another biopsy confirmed the original diagnosis. She died 1 year after presentation.

Case 2

A 7-month-old girl presented with a right facial nerve palsy and bilateral purulent discharge with subtotal tympanic membrane perforations. She was systemically well and afebrile. CT scan showed destructive lytic changes in the right mastoid (Fig. 4.8a) and some mastoid changes in the contralateral temporal bone as well (Fig. 4.8b).

A diagnosis of lymphoma was entertained. A right cortical mastoidectomy for biopsy revealed acute inflammatory granulation tissue and osteomyelitis. Pseudomonas aeruginosa was cultured from the mastoid biopsy samples. She was treated as a necrotizing acute otitis media and responded completely.

Rhabdomyosarcoma

Definition

Rhabdomyosarcoma (RMS) is a malignant tumor of rhabdomyoblasts which are mesenchymal precursors of skeletal muscle. Within the head and neck, it is found more often in the anterior skull base and orbits than around the ear. Although rare, it is the most common malignancy of the temporal bone in children. Prognosis depends on histological subtype, location, age, and molecular biology. Classification of different histological subtypes of rhabdomyosarcoma has evolved as more data on prognosis have accumulated. Superficial head and neck RMS is considered a favorable location, but parameningeal disease, incomplete resection, and the presence of metastases adversely affect prognosis. The age range of 1–10 years has optimal prognosis [89].

The 1995 International Classification of Rhabdomyosarcoma (IRC) consolidated previous classifications and distinguished spindle cell RMS with a superior prognosis, typical embryonal RMS with an intermediate prognosis, and alveolar and undifferentiated RMS with a poor prognosis [90]. Published case series suggest that embryonal RMS is the commonest subtype found in the temporal bone [91, 92].

Botryoid RMS (which implies a grape-like configuration under an intact epithelial layer) was an additional subtype included in the IRC classification, but since then this has been incorporated within the embryonal subtype as the prognosis is typically similar. Of potential relevance to this chapter however, botryoid RMS may have a more favorable prognosis compared with embryonal or spindle RMS of the head and neck in children [93]. Spindle cell RMS can occur in the head and neck in adults where it has a poorer prognosis, but in children outcome is generally similar to embryonal RMS, except when in a parameningeal location when prognosis is worse [93]. Sclerosing RMS is a more recently defined histological subtype, a variant of spindle cell RMS with increased hyalinization and matrix formation. It is less common in children than adults. Although sclerosing RMS has a worse prognosis in adults, in children outcome seems to be more favorable, having similar survival rates to embryonal RMS [93].

Genetic studies are now providing an additional method of risk stratification for predicting outcome. At least in adults, mutation in the MYOD1 gene may account for the worse prognosis seen with spindle cell and sclerosing RMS. More recently it has become apparent that fusion of the PAX3 or PAX7 genes to the FOXO1 gene adversely affects prognosis significantly in children, so that fusion-negative alveolar RMS may now be reclassified as being of low risk [94].

Temporal bone RMS is sufficiently rare that prognostication has to be extrapolated from more generalized experience. Event-free 3-year survival of around 90% could be expected for low-risk tumors such as non-metastatic embryonal RMS without parameningeal location (e.g., tumors of the ear canal). Intermediate risk RMS (e.g., alveolar RMS or intracranial extension) has survival of around 60–80%, whereas metastatic disease has <50% 3-year survival [89].

Clinical Presentation

RMS is most often seen in young children, under the age of 10 years and predominantly under age 5 years [91, 92, 95, 96]. Presenting features with temporal bone RMS may include otalgia, bloody otorrhea, mass in the middle ear (Fig. 4.9a), ear canal or around the ear including extension of a mass to the postnasal space (Fig. 4.9b), or nasopharynx. Facial or other cranial nerve palsies are common [92].

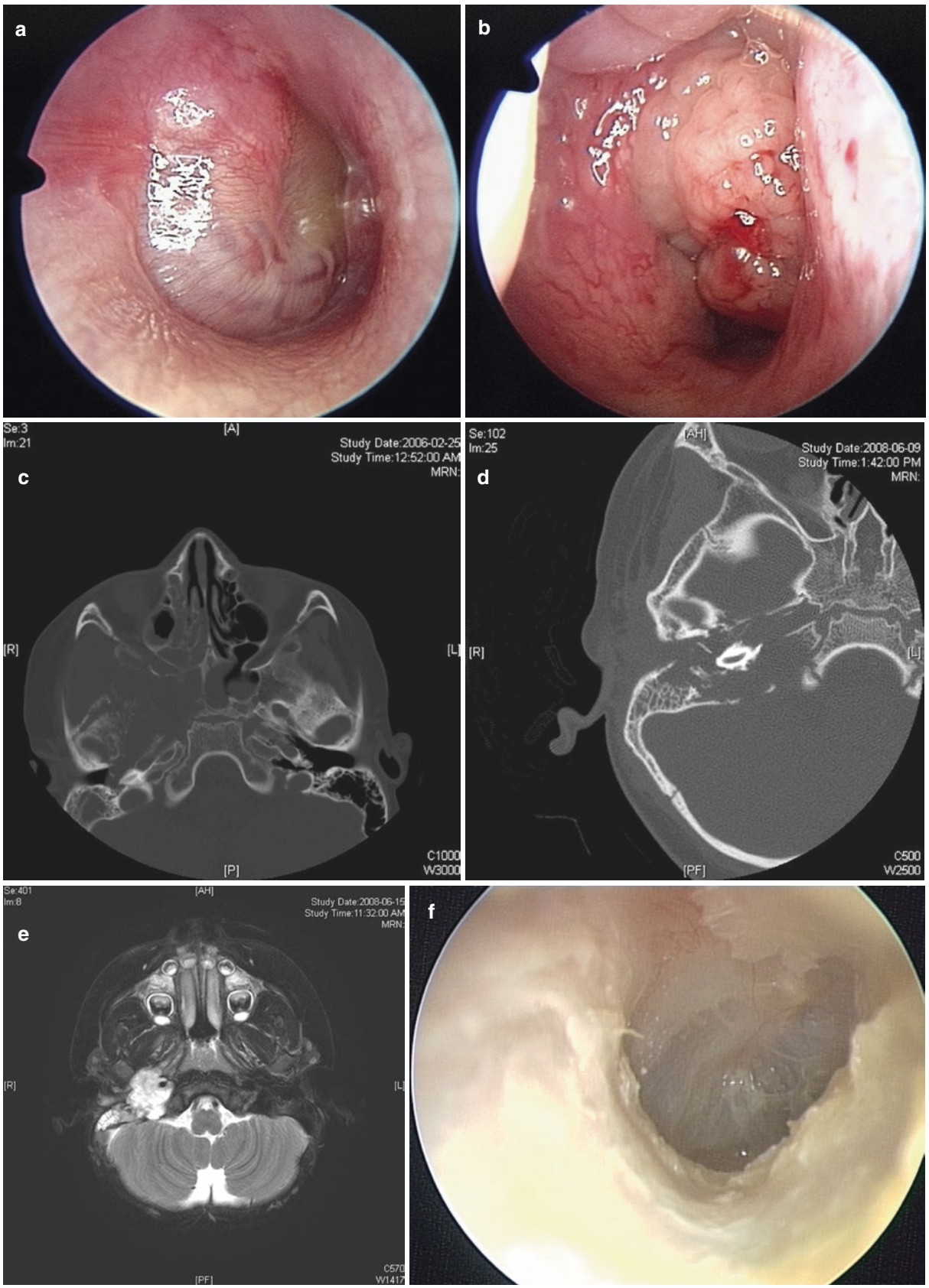

Fig. 4.9 (**a**) Otoscopy showing mass behind right tympanic membrane. (**b**) Rhinoscopy showing mass in postnasal space. (**c**) Axial CT showing extensive destruction of bone at skull base. (**d**) Axial CT showing extensive destruction of temporal bone. (**e**) Axial MRI showing extensive destruction of the skull base and temporal bone with encasement of carotid artery. (**f**) Posttreatment otoscopic findings in patient with extensive RMS. The mass is no longer visible in the middle ear

Unilateral hearing loss may be present but is often unnoticed in young children. Presentation around the ear may be indicative of a more extensive skull base lesion and the disease is often extensive by the time it is recognized [97]. Smaller tumors localized to the external ear have been reported and have a much more favorable prognosis [95, 96].

Several syndromes with known genetic mutations such as Li-Fraumeni syndrome, Noonan syndrome, Beckwith-Wiedemann syndrome, von Recklinghausen disease, and cardiofaciocutaneous syndrome are associated with an increased risk of developing RMS.

Differential Diagnosis

A benign aural polyp from cholesteatoma or a keratosis obturans/wax impaction scenario is a much more common cause of an irregularly-surfaced fleshy mass in the ear canal than RMS. The presence of periauricular swelling, lymphadenopathy, and facial weakness will make the diagnosis of RMS more obvious, but it should not be forgotten that RMS may present like chronic suppurative otitis media [92]. Other causes of a destructive lesion in the temporal bone include histiocytosis and rarer malignancies such as Ewing sarcoma or osteosarcoma.

Radiological Features

The characteristic features of RMS are of an invasive destructive lesion (Figs. 4.9c, 4.9d and 4.9e).

It can be difficult to distinguish RMS from other neoplasms of the skull base with imaging alone [98]. One suggested feature of RMS compared with histiocytosis is localization to the petrous apex or middle ear rather than the mastoid though this is not an invariable finding [66].

Management

Pretreatment evaluation of patients with suspected RMS includes surgical biopsy, CT and MRI imaging, evaluation for metastatic spread, and lumbar puncture cytology to assess for parameningeal spread.

The prognosis for children with RMS has improved over recent decades as treatment protocols with multiagent chemotherapy, surgery, and radiotherapy have been refined [99]. When possible, complete surgical resection is preferred, though this may not be achievable with acceptable morbidity according to tumor extent and location. In addition, a chemotherapy regime is selected according to risk stratification based on histology, location, extent, fusion-status, and metastases. Challenges that impact survival from temporal bone RMS are the parameningeal location, the risk of incomplete tumor resection, and likelihood of metastases at the time of presentation. Nevertheless, combined modality treatment with chemotherapy and intensity-modulated radiotherapy has been found to provide good outcomes in extensive unresectable embryonal RMS of the temporal bone in children [91].

Treatment is typically guided by study protocols from, for example, the Intergroup Rhabdomyosarcoma Study Group/Children's Oncology Group. In keeping with the standard of care for pediatric head and neck malignancies, the involvement of a multidisciplinary team with requisite surgical and oncological experience is required to optimize an individualized management plan for the specifics of each child.

Clinical Example

A 6-year-old boy presented with right-sided otalgia, sore throat, headache, vomiting, weight loss, and decreased appetite for 1 month. He also had torticollis for the previous 5–7 days. A right seventh nerve palsy was noted on the clinical exam. Otoscopy showed a mass behind an intact eardrum (Fig. 4.9a) and a mass in the postnasal space (Fig. 4.9b).

Imaging at presentation included CT and MRI which showed an extensive destructive process of the right temporal bone, skull base, and extension of the mass in the right postnasal space (Figs. 4.9c, 4.9d and 4.9e). He was treated with chemotherapy and radiation with a good clinical response as evidenced by improvement of the otoscopic exam at 8 months (Fig. 4.9f).

Unfortunately, the patient died of metastatic disease including to the lungs 1.5 years after presentation.

Osteosarcoma

Definition

Osteosarcoma, also known as osteogenic sarcoma, is a malignant tumor of bone in which sarcoma cells generate osteoid (the non-mineralized constituent of bone) into which spicules of mineralized bone may form. Although it is the most common primary bone malignancy in children, involvement of the skull and especially the temporal bone is very rare, with long bones being most commonly affected. Published experience of temporal bone osteosarcoma is scant [100–102].

Clinical Presentation

Pain and an irregularly shaped hard mass fixed to bone are the characteristic features of osteosarcoma. Presentation in long bones peaks between age 10 and 25 years, but osteosarcoma of the jaw is said to occur later [103]. Metastatic spread is hematogenous to the lungs and sometimes other bones, but typically not to lymph nodes. Children with retinoblastoma can develop osteosarcoma as a second primary malignancy and one such

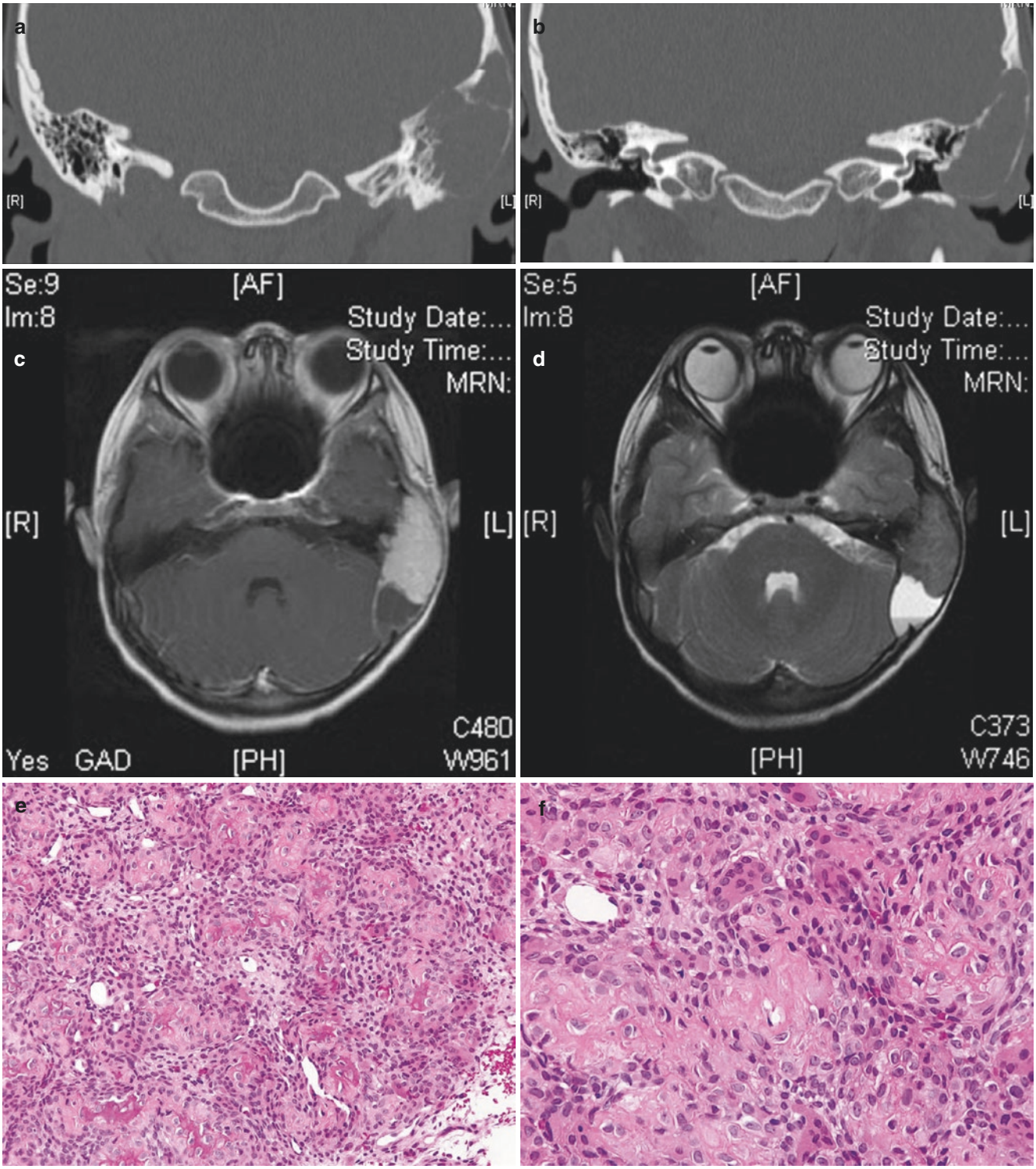

Fig. 4.10 (**a**) Coronal CT demonstrates an expansive lytic lesion in the mastoid with elevation of periosteum from adjacent cortical bone by the tumor giving rise to a segment of reactive bone known as Codman's triangle superiorly. (**b**) Coronal CT showing the expansive lytic lesion has occluded the ear canal. (**c**) Axial T1 MRI with gadolinium showing fluid-filled cyst consistent with an aneurysmal bone cyst within the lesion. (**d**) Axial T2 frFSE MRI showing fluid-filled cyst consistent with an aneurysmal bone cyst within the lesion. (**e**) Sections showed a solid bone lesion with crowded irregularly shaped malignant osteoid units that contains osteoblasts with mild atypia. They are also present within the stroma between the malignant osteoids. (**f**) Higher magnification reveals the cytological features of this low-grade osteoblastic osteosarcoma with osteoblasts displaying mild nuclear anaplasia They also infiltrate the stroma of the interosseous spaces. Infiltrates of reactive osteoclastic giant cell are also present. (**g**) Section of the excised tumor revealed osteoblasts with more nuclear and cytological atypia within the malignant osteoids as well as the stroma. (**h**) Follow-up coronal CT 4 years after excision showed no evidence of recurrence

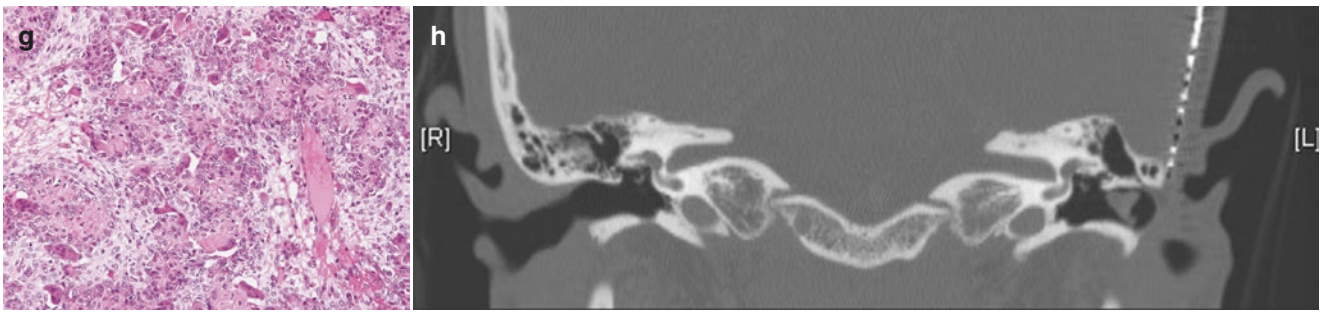

Fig. 4.10 (continued)

case has been reported in the temporal bone [100]. This patient died from local recurrence after treatment with chemo-radiotherapy. An osteoblastic temporal bone osteosarcoma has been reported in a 21-year-old male with a strong family history of osteochondromatosis. The tumor rapidly invaded the mastoid, middle ear, and suboccipital region and he died within 3 months of treatment with radiotherapy [102]. Other reported predisposing causes of osteosarcoma include irradiation, Li–Fraumeni syndrome, fibrous dysplasia, and Paget's disease [103, 104].

Generally, the prognosis is best in younger children with no metastases at presentation, good response to neoadjuvant chemotherapy, and fibroblastic or telangiectatic subtypes [105]. Outcomes are worse with osteoblastic or chondroblastic subtypes and Paget's disease. Survivors are at risk of second malignant neoplasms [105].

Differential Diagnosis

Histiocytosis and rhabdomyosarcoma are more common causes of painful tumors in the temporal bone. In contrast they cause destruction of bone and not deposition of osteoid.

Radiologic Features

The classic radiographic appearance of osteosarcoma is a "sun-ray" appearance from bony speculation which can sometimes be seen on plain radiographs and CT. Elevation of periosteum from adjacent cortical bone by the tumor may give rise to segments of reactive bone known as Codman's triangle (Fig. 4.10a).

Management

Surgical biopsy is required to confirm the diagnosis. It is important to sample osteoid from within the tumor and not just the reactive bone of Codman's triangle at the edge. Imaging with CT and MRI is required to carefully assess extent before planning surgery. Screening for pulmonary metastases should be performed before planning treatment. Published literature is not available to guide treatment, but extrapolation from treatment of osteosarcoma at other locations suggests that complete surgical resection with pre- and postoperative chemotherapy be considered. Published data suggest a poor prognosis can be expected [100–102].

Clinical Example

A 12-year old boy presented with a mass behind the left ear noticed by the parents after a haircut. The child believed it had been present for at least four months and felt it had been slowly enlarging. There was no associated pain or hearing loss.

On examination the ear canal was occluded by a mass and there was a bony prominence behind the ear. CT showed an expansive lytic lesion which had lifted the periosteum producing reactive bone known as Codman's triangle (Figs. 4.10a and 4.10b).

There was also a fluid-filled cyst consistent with an aneurysmal bone cyst within the lesion which could be better appreciated on the MRI (Figs. 4.10c and 4.10d).

Biopsy through the mastoid showed a permeative growth pattern adjacent to native bone (Figs. 4.10e, 4.10f and 4.10g) consistent with a low-grade osteoblastic osteosarcoma.

Excision was performed with neurosurgery via conservative partial temporal bone excision and split cranial bone grafting. Clinical follow-up as well as a CT scan at 4 years showed no evidence of recurrence (Fig. 4.10h).

Ewing Sarcoma

Definition

Ewing sarcoma is the second most common bone malignancy of childhood after osteosarcoma. The small round tumor cells are poorly differentiated which lead to controversy over classification in the past [103]. A translocation between chromosomes 11 and 22 is commonly implicated.

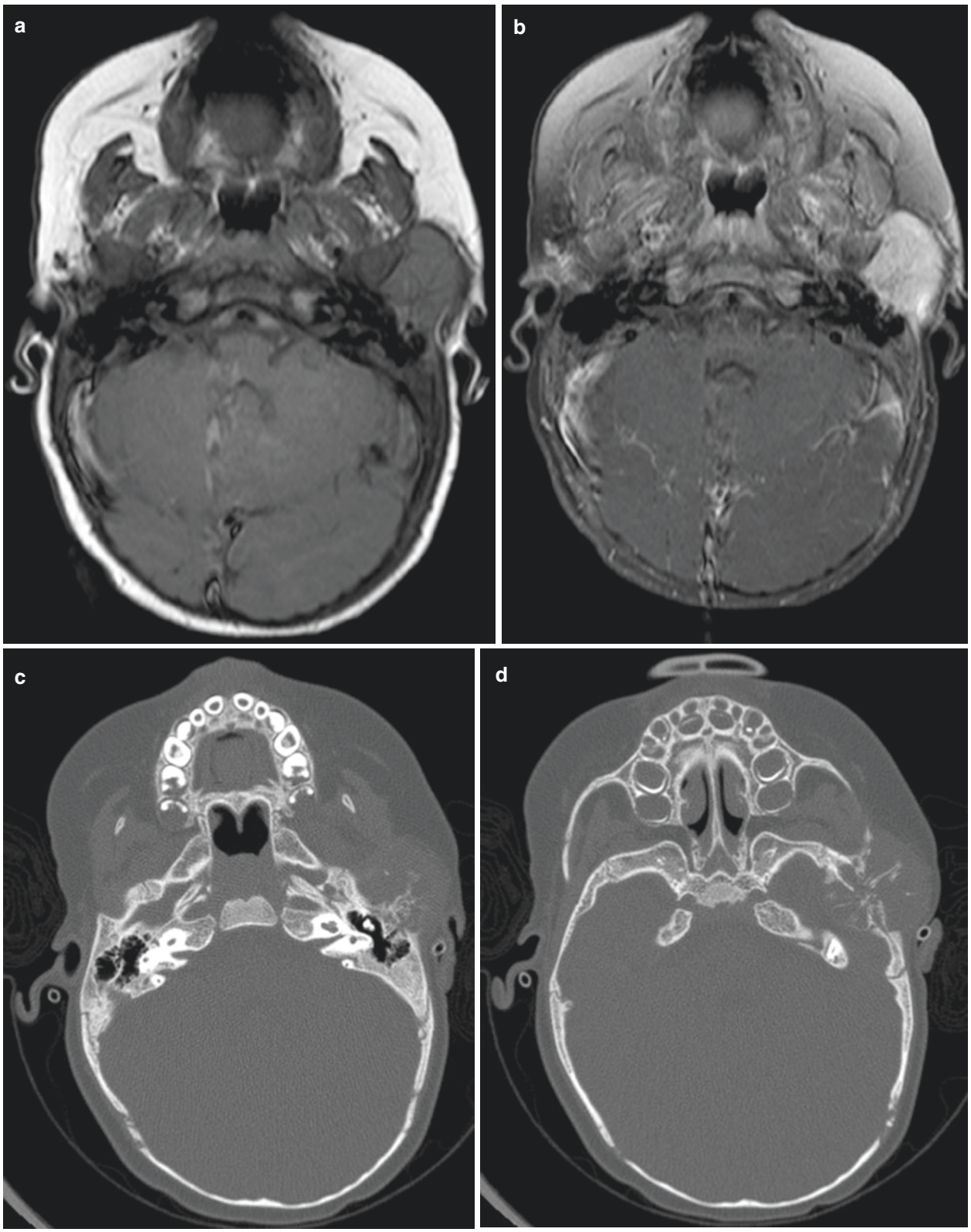

Fig. 4.11 (**a**) Axial T1 MRI of Ewing sarcoma. MRI can be valuable to delineate the extent of adjacent soft tissue involvement, particularly to assess for dural invasion. (**b**) Axial T1 MRI with gadolinium of Ewing sarcoma. MRI can be valuable to delineate the extent of adjacent soft tissue involvement, particularly to assess for dural invasion. (**c**) Axial CT in Ewing sarcoma forms radiolucent osteolytic lesions that may extend through cortical bone into adjacent soft tissue. (**d**) The characteristic radiographic finding in Ewing sarcoma is an "onion skin" appearance caused by layering of thin shells of bone from periosteal reaction around the tumor. As with osteosarcoma, Codman's triangle may develop at the edge of the lesion

Ewing sarcoma typically involves the long bones, pelvis, or spine. Published experience of Ewing sarcoma in the temporal bone is limited to a fairly small number of case reports [106–112].

Clinical Presentation

Ewing sarcoma of the temporal bone has been identified in infants as young as 5 months and 18 months, but other reported cases were in older children. Pain is the most common presenting symptom. Local swelling and invasion may cause symptoms according to location, with facial nerve palsy, proptosis, and raised intracranial pressure reported [106, 109, 110]. Metastasis by hematogenous spread can occur and has been reported in the lungs of one child with extensive Ewing sarcoma of the temporal bone and skull base [110]. Racial differences in molecular biology have been reported and may account for a worse prognosis in children with African ancestry [104].

Differential Diagnosis

Histiocytosis and rhabdomyosarcoma are more common neoplastic causes of pain and swelling around the temporal bone.

Radiologic Features

Ewing sarcoma forms radiolucent osteolytic lesions that may extend through cortical bone into adjacent soft tissue (Figs. 4.11a–4.11d). The characteristic radiographic finding in Ewing sarcoma is an "onion skin" appearance caused by layering of thin shells of bone from periosteal reaction around the tumor. As with osteosarcoma, Codman's triangle may develop at the edge of the lesion. Skip lesions may grow along Haversian canals and be visible on CT scan. MRI can be valuable to delineate the extent of adjacent soft tissue involvement, particularly to assess for dural invasion.

When considering Ewing sarcoma at all locations, prognosis is worse with metastatic disease, large tumor size, elevated serum LDH, and older age [104].

Management

Surgical biopsy is required to confirm the diagnosis. Imaging with CT and MRI is required to carefully assess extent before planning surgery. Dural invasion implies a worse prognosis, so lumbar puncture for CSF cytology may be worthwhile. Screening for pulmonary metastases should be performed before planning treatment. Bone marrow biopsy can be included to assess for chromosomal translocations. Multidrug chemotherapy with complete surgical resection is the treatment of choice when possible. Surgery should include the biopsy tract and wide margins around the tumor when the extent and location allows. Radiotherapy is most often reserved for cases where complete resection cannot be achieved [104], but may not prevent death from disease [109, 110].

The complexity and potential morbidity of the resection and consequences of stunted cranial growth from radiotherapy in young children mean that multidisciplinary team planning is critical. The combined services of an otologist, head and neck surgeon, craniofacial surgeon, neurosurgeon, oncologist, radiotherapist, and sometimes palliative care provider, ideally all with pediatric experience, may be required to optimize care for the child.

Clinical Example

A 12-month old girl presented with a rapidly growing hard lump infront of her left ear. Biopsy and imaging (Fig. 4.11) indentified a Ewing sarcoma involving the zygoma with extension into the middle ear and middle cranial fossa. Neoadjuvant chemotherapy was followed by complete surgical resection and a completion course of chemotherapy with no sign of recurrence after 5 years.

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