The Journal of Laryngology and Otology
April 2000, Vol. **114**, pp. 248–253

Main Articles

A systematic approach to interpretation of computed tomography scans prior to surgery of middle ear cholesteatoma

SIMON WATTS, F.R.C.S., LIAM MARTIN FLOOD, F.R.C.S., KEVIN CLIFFORD, F.R.C.R.*

Abstract
The foundation of mastoid surgery for cholesteatoma has traditionally been a thorough knowledge of the anatomy and familiarity with landmarks, constant alertness to detect unsuspected complications and the experience to tailor the surgery to the pathology encountered. Whilst not indispensable, computed tomography (CT) scanning is a useful adjunct whose potential predictive value is only truly appreciated by skilled interpretation. We present a guide to analysis to maximize the value of pre-operative radiology.

Key words: Tomography, X-ray computed; Temporal bone; Cholesteatoma

Introduction

It is accepted that CT imaging of the paranasal sinuses is essential in planning endoscopic sinus surgery to reduce the risk to adjacent structures such as the orbit and skull base, to evaluate disease and to compensate for any disorientation associated with the restricted endoscopic visual field.[1]

Historically mastoid surgery has been undertaken with otoscopy, audiometry and possibly plain X-rays as the only pre-operative investigations. The advent of high definition CT scanning in the 1980s has allowed superb pre-operative imaging of anatomy, some evidence of the extent of the disease and a screen for asymptomatic complications as will be shown.

It has not, however, gained wide acceptance as an essential aid to planning surgery, most otologists reserving scans for selected cases such as patients with complications of chronic suppurative otitis media (CSOM), with suspected congenital abnormalities or with loss of landmarks due to previous surgery.[2] Routine CT scanning prior to all surgery of cholesteatoma can only be justified if it can be shown that clinical management is influenced. The familiarity that comes with experience and close cooperation between otologist and radiologist is essential.

Radiological anatomy

Figure 1a is the scout film. This sagittal view of the skull is traversed by multiple vertical lines, which demonstrate the plane of scanning (coronal), the thickness of slice (1.5 mm) and the region studied. Slices are numbered to identify subsequent images.

Figure 1b is the most anterior of the scans of the right ear. The arrow points to the healthily ventilated anterior tympanic cavity and bony orifice of the eustachian tube. Lateral to it is the temporomandibular joint and medially the large carotid canal. A smaller indentation in the upper edge of the partition between carotid and eustachian canal marks the canal for tensor tympani.

Figure 1c lies 3 mm posteriorly. The malleus head is apparent in the ventilated epitympanum. Medially is the coiled cochlea and below it the carotid canal. Superior to the cochlea is the facial nerve, (solid arrow). This is seen as a double canal, medially as the supralabyrinthine segment approaches the geniculate ganglion and laterally as it recedes in its horizontal portion. The appearance has often been likened to the dreaded 'snake's eyes' seen by the unfortunate surgeon who enters the posterior semicircular canal while approaching the endolymphatic sac! The tendon of tensor tympani can again be seen as a faint bony defect below the horizontal segment of the facial nerve.

Figure 1d lies a further 3 mm posteriorly. The arrow indicates the anterior limb of the lateral semicircular canal as it leaves the vestibule, the superior canal passing perpendicularly. On its under-

From the Department of Otolaryngology, North Riding Infirmary, Middlesbrough and the Department of Radiology*, South Cleveland Hospital, Middlesbrough, UK.
Accepted for publication: 20 December 1999.

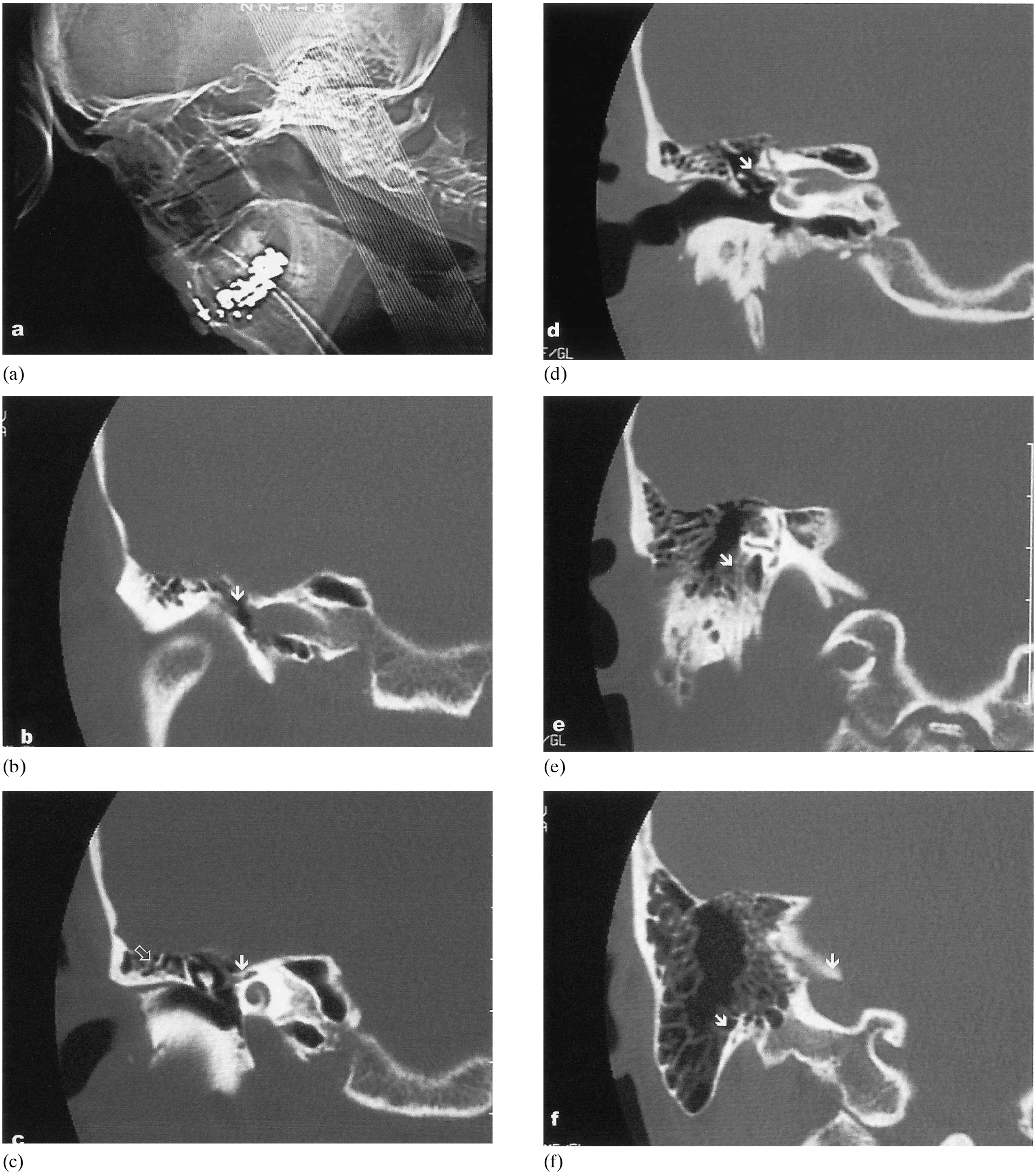

Fig. 1

Sequential coronal slices through a healthy right middle ear from anterior (Figure 1b) to posterior (Figure 1f).

surface is a faint indentation, the facial nerve and, infero-medial to that, the oval window niche. Immediately lateral to the canal is a small white dot, the short process of the incus and, further laterally still, the sharp angle of an intact scutum. External and internal auditory canals are both seen on this slice.

Figure 1e demonstrates the descending facial nerve (arrowed). Its upper extent, the second genu, lies beneath the posterior limb of the lateral semicircular canal, which is now returning to the vestibule. The black, ventilated, space medial to the descending facial nerve is the sinus tympani and, further medially the jugular bulb.

Figure 1f, the most posterior of these slices, shows a well pneumatized cellular mastoid system. The lower arrow indicates the digastric ridge, which can be traced forward to the stylomastoid foramen (compare with Figure 1e). The upper smaller arrow points to the sigmoid sinus.

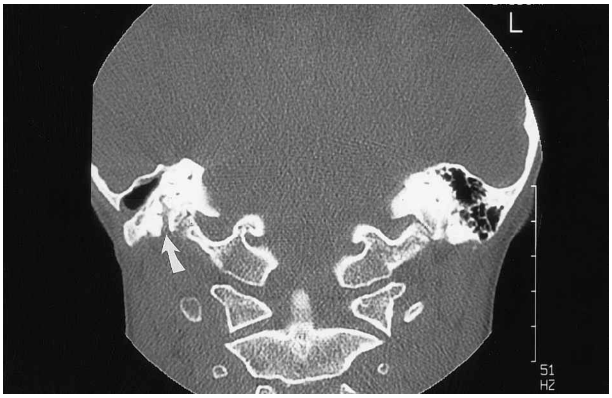

FIG. 2

Coronal CT through both mastoid systems, the left healthy and pneumatized, the right a small cavity lateral to the descending facial nerve (arrowed).

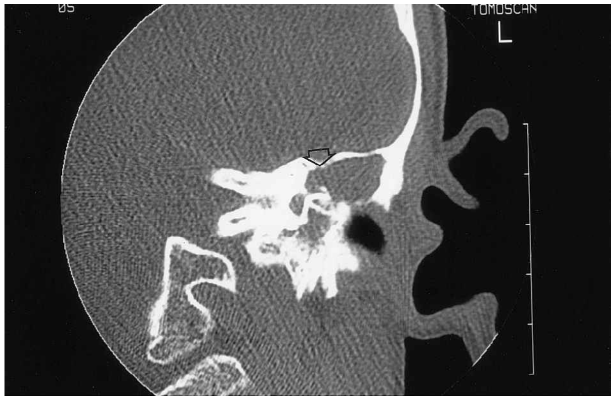

FIG. 4

Contralateral ear demonstrating a large mastoid defect eroding the upper surface of the lateral and the superior semicircular canals (arrowed).

All these anatomical relationships are very familiar as surgical landmarks to the experienced otologist and become readily apparent on imaging, with practice.

Systematic interpretation of pathology

Step 1 – Orientation

Multiple sheets of films, possibly in axial as well as coronal planes demonstrating either or both ears can be confusing. The scout film (Figure 1a) must be identified to determine the axis of view, the thickness of cuts and the areas examined. Films may show both ears on a single image (Figure 2) or concentrate on the ear showing pathology (Figures 3–8). The views must be correctly displayed to illustrate left and right. It should be noted that, by convention, 'L' in most of the scans (Figures 3–8) indicates the left side of the image; only in Figure 4 are we examining the left side of the patient! In the authors' experience, even the legend 'RT. SIDE' (Figure 3) does not avoid confusion amongst novices. The most anterior picture will show the temporomandibular joint, the most posterior, the mastoid region.

Step 2 – Examine the middle ear cleft

In health, this involves tracing the black aerated pathway from the eustachian tube, through the tympanic cavity and back into the mastoid system. Any pathology such as cholesteatoma, polyp or effusion is reliably demonstrated (if not always differentiated) as an opacity, e.g. compare the epitympanium in Figure 3 with that in Figure 1c. Ossicular erosion may be evident as in Figure 5 (again compare with 1c) where the malleus head is absent. The mastoid system can vary from the extensive ventilated cellular mastoid system extending to the petrous apex, of Figure 1f to the contracted opaque antrum in Figure 6. In the absence of obvious pathology further interpretation might now be abandoned and the clinician return to the auriscope!

Step 3 – Evaluate the surgical access to the middle ear cleft

The approach to any pathology may be influenced by the anatomy lateral to the tympanic cleft. The height of the dura will limit the approach to the epitympanum and can vary from the high, cellular, 'easy' access of Figure 1c (open arrow) to the dipping in Figure 5 where middle fossa dura is in contact with the roof of the external canal. Substantial defects in the tegmen (Figure 7) whether due to pathology or previous surgery are easily identified. A cellular mastoid system as in Figure 1f may encourage an

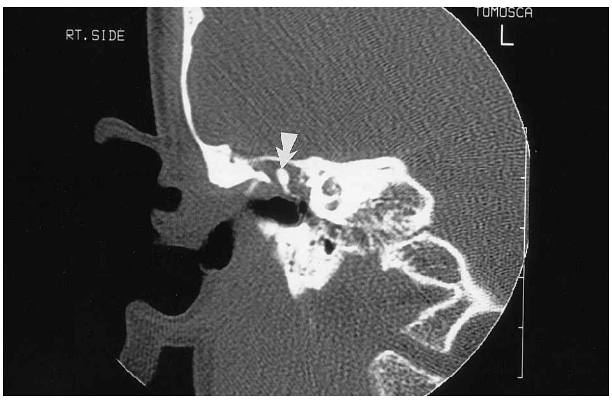

FIG. 3

Coronal section of the right anterior mesotympanum demonstrating attic disease enveloping an intact malleus head (arrowed).

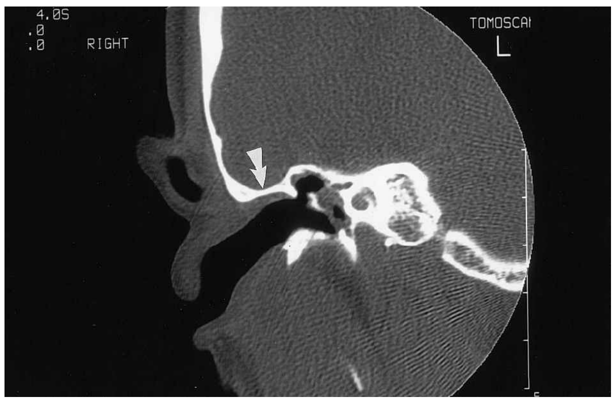

FIG. 5

Low lying dura (arrowed) restricting access to an attic perforation with erosion of the malleus head.

https://doi.org/10.1258/0022215001905454 Published online by Cambridge University Press

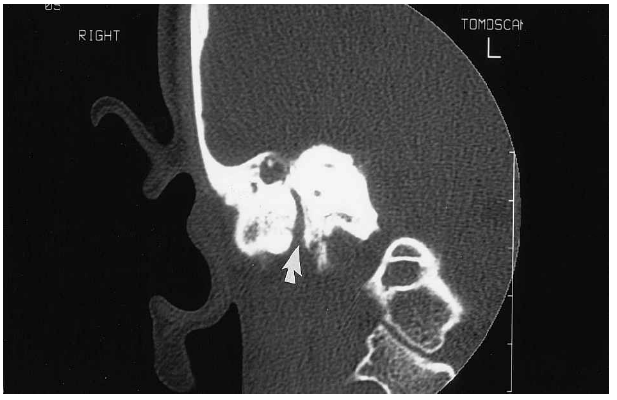

FIG. 6

A more posterior slice demonstrating an opaque mastoid antrum with a (surgically verified) tegmen defect but intact descending facial canal (arrowed).

intact canal wall, transmastoid approach. The contracted system of Figure 6 may suggest the small cavity atticotomy – antrostomy approach.

Step 4 – Follow the course of facial nerve

This can be followed from the geniculate ganglion (Figure 5) through its horizontal portion to the second genu and descending segment (Figures 2, 6 and 8). The intact bony wall of Figures 3 and 6 compares with the dehiscence at the second genu in Figure 8.

Step 5 – Check the integrity of the labyrinth

The cochlea is easily identified but its cortex is rarely eroded. The stapes footplate is seldom seem and so a fistula will not be evident. Erosion of the apex of the lateral semicircular canal (Figure 7) may require axial scans for confirmation. (If fistula is suggested, it is worth reassessing the facial nerve for erosion of its Fallopian canal). Erosion of the superior canal (Figure 3) and extension deep to the labyrinth is more readily apparent.

Step 6 – Identify the adjacent vascular compartments

The carotid canal is seen inferior to the cochlea in Figures 1c and 5 but is of little surgical relevance in CSOM. Serial sections can illustrate dehiscence of the sigmoid plate and exposure of the posterior fossa dura although not illustrated here.

Scanning technique

Routine CT scanning of the middle ear requires coronal scans with the patient prone, without i.v. contrast and applying the following parameters: 512 matrix; 250 field of view, or zoom; 4 second scan time (the maximum available); 1.5 mm contiguous slices; 1H filter (edge enhancement); 120 kV, 100 mA exposure; 1.5 mm table index (to give contiguous slices); fast scan mode; beam hardening correction switched on; approximately 25 slices performed per examination.

FIG. 7

Cholesteatoma recurrence following previous combined approach tympanoplasty. The roof of the external canal is eroded and there is a defect in the floor of the middle cranial fossa (small arrow). There is a fistula into the LSCC with a profound sensorineural loss (larger arrow).

Discussion

Routine radiological assessment prior to mastoid surgery can only be justified when the information obtained alters clinical management. Surgery may be facilitated if imaging can reliably demonstrate the relevant anatomy, the nature and extent of pathology and the presence of asymptomatic complications. To be clinically effective, it must be shown that prior recognition of such findings, that would eventually be apparent on exploration anyway, is of advantage.

Imaging will be of greatest value to the surgeon who is prepared to tailor the surgical approach to the radiological findings. The flexible operator will employ intact canal wall versus open techniques and the small cavity attico-antrostomy approach guided by knowledge of mastoid cellularity, extent of disease and complications.

Interpretation of CT scans obviously requires an enthusiastic otologist prepared to benefit from the knowledge of an expert radiologist who can produce images of the quality demonstrated here. With time the surgeon gains increased experience of correlating CT with eventual surgical findings. Coronal scans are

FIG. 8

Posteriorly the opaque mastoid cavity abuts onto an exposed second genu of the facial nerve (arrowed).

https://doi.org/10.1258/0022215001905454 Published online by Cambridge University Press

also relatively easily understood by the patient. A few minutes discussion of the images, demonstrating the course of the facial nerve, the relationship of the inner ear and the damage to the ossicles can be of great help in pre-operative counselling. Such scans can illustrate both the need and also the hazards of surgery. Imaging can also enhance the trainee's knowledge of surgical anatomy.[3] Although a relatively minor consideration as yet, any pre-operative documentation of disease can only be of medico-legal value.

The extensive literature has also presented the counter-arguments and dilemmas raised. The problems highlighted include: cost; radiation dosage; inability of imaging to differentiate cholesteatomas from granulations, mucosal oedema or even effusion; clinical irrelevance in merely demonstrating what will be discovered in surgery ultimately; relative lack of sensitivity in providing a false reassurance that a complication such as a fistula or dehiscent facial nerve is absent when they should always be assumed;[4] the decision whether to restrict scanning to specific indications or employ it as a pre-operative routine; the difficulty in obtaining CT scans in those where it is most indicated, i.e. emergencies and children.

Cost

In our practice, the marginal cost of the protocol described above has been calculated as £70.

Radiation dosage

Calculated from a head phantom, using the above factors, the effective dose was found to be 2.319 milli-Sieverts (mSv) for 136 slices. Thus the average dose per slice is equal to 0.017 mSv. This is about the same dose as one chest X-ray. Therefore for 25 slices, the total dose is 0.43 mSv.

The typical effective dose of a standard CT brain scan is, in comparison, over four times greater at 2 mSv. In practice, coronal scanning of the temporal bone produces minimal irradiation of the most sensitive target tissue, the lens of the eye and the theoretical risk of cataract formation is far greater in CT scanning of the paranasal sinuses.

Diagnostic limitations

CT will reliably detect but not always characterize disease. In a rare, truly blinded and prospective study of the value of CT studies of CSOM, O'Reilly *et al.*,[4] demonstrated 100 per cent sensitivity in both detecting a mass in the middle ear and mastoid and in determining the extent of disease. Conversely, a normal CT appearance reliably excludes middle-ear pathology in stenosis of the external canal or refractory otitis externa.

Unfortunately cholesteatoma sac, associated granulation tissue, mucosal oedema and effusion may be indistinguishable on CT scanning.[2,5] Although cholesteatoma is said to show a lower attenuation than granulation tissue the difference is subtle and only magnetic resonance imaging can differentiate the two.[6] After clinical examination, otoscopy, and a diagnosis of cholesteatoma, CT can determine its extent by revealing the combination of a soft tissue mass and bone erosion, with 80 per cent specificity.[4,7]

Clinical irrelevance in predicting problems

Indeed, challenging anatomy limiting access will become obvious as drilling proceeds but foreknowledge may influence the choice of approach. Anticipation of dural exposure, facial nerve dehiscence and labyrinthine fistula can only be of advantage.

Figures 3 and 4 demonstrate representative scans of the two temporal bones of a 12-year-old boy presenting with bilateral attic cholesteatoma. The right ear (Figure 3) showed normal hearing on audiometry, the left (Figure 4), a 40 dB air bone gap with normal bone conduction, the conductive nature of the loss confirmed on tuning fork testing. CT scanning confirmed attic disease in the right, normal hearing ear and erosion of the superior and lateral semicircular canal on the left. At review a fistula test proved negative and, using these images as illustrations, the findings and surgical risks were discussed. A left modified radical mastoidectomy, with presentation of the matrix overlying the fistula resulted in unchanged hearing and a dry cavity. Surgery on the right better-hearing ear is planned and a hearing aid is available for the left post-operatively. Had an unrecognized fistula been entered, labyrinthitis might have ensued and the patient would now be facing surgery on the right only hearing ear!

It must be conceded that most iatrogenic injuries to the facial nerve result from disorientation and failure to identify surgical landmarks rather than from the abnormal course or dehiscence, that scanning might have predicted.[8]

Lack of sensitivity/specificity for complications

Obviously a reassuring scan should never cause the operator to abandon caution when approaching the lateral semicircular canal, the facial nerve and ossicular chain. Studies of sensitivity/specificity may not reflect the advances in the past 10 years and may, for example largely rely on axial images.[4] Axial scanning is only of value in confirming a suspicion of canal fistula on coronal imaging, in demonstrating depth of the sinus tympani and evaluating petrous apex disease, but is very insensitive to tegmen erosion, ossicular disease and facial nerve exposure, in our experience.

Universal or selective scanning?

Few authors recommend scanning as a routine prior to all mastoid surgery but, with improving resolution and therefore sensitivity this may evolve. In planning revision surgery, especially after intact canal wall procedures, residual diseased air cells in the sino-dural angle, tegmen, mastoid tip and petrous apex together with recurrent cholesteatoma can be demonstrated.[9] Indeed it is argued that imaging can replace the 'second look' tympanotomy.[10,11]

Impracticalities of CT scanning

Waiting times and availability of first rate CT scanning facilities may restrict some departments' access. Unfortunately, children who tend to show the most aggressive cholesteatoma, may be non-compliant with scanning and introduce motion artefacts. Few intratemporal complications of CSOM require such immediate surgery as to prevent radiology. The direst emergency, intracranial sepsis, will certainly require neuroradiology but sophisticated imaging of the temporal bone may well have to be sacrificed.

Summary

O'Donoghue, in a detailed response to Blevins and Carter's literature review[3] felt there was not a strong case for routine systematic pre-operative imaging but that 'clinicians should have a low threshold for availing of what is an inexpensive, non-invasive investigation, that can often yield useful information'. Experience and familiarity with imaging of the chronically-infected middle ear serves to demonstrate its value.

In our practice, CT evaluation has become the norm prior to the majority of mastoid surgery and is the subject of a prospective study of its clinical relevance.

Acknowledgements

The authors are grateful to Ear, Nose, Throat and Eye Research (ENTER) for its help in producing this paper.

References

1 Mason JD, Jones NS, Hughes RJ, Holland IM. A systematic approach to the interpretation of computed tomography scans prior to endoscopic sinus surgery. *J Laryngol Otol* 1998;**112**:986–90
2 Phelps PD, Wright A. Imaging cholesteatoma. *Clin Radiol* 1990;**41**:156–62
3 Blevins NH, Carter BL. Routine pre-operative imaging in chronic ear surgery. *Am J Otol* 1998;**19**:527–38
4 O'Reilly BJ, Chevretton EB, Wylie I, Thakkar C, Butler P, Sathuanathan N, *et al.* The value of CT scanning in chronic suppurative otitis media. *J Laryngol Otol* 1991;**105**:990–4
5 Jackler RK, Dillon WP, Schindler RA. Computerised tomography in suppurative ear disease: a correlation of surgical and radiographic findings. *Laryngoscope* 1984;**94**:746–52
6 Mafee MF, Levin BC, Applebaum EL, Campos M, James CF. Cholesteatoma of the middle ear and mastoid. *Otolaryngol Clin North Am* 1988;**21**:265–93
7 O'Donoghue GM, Bates GJ, Anslow P, Rothera MP. The predictive value of high resolution computed tomography in chronic suppurative ear disease. *Clin Otolaryngol* 1987;**12**:89–96
8 Green JD, Shelton C, Brackmann DE. Iatrogenic facial nerve injury during otologic surgery. *Laryngoscope* 1994;**104**:922–6
9 Campbell JP, Pillsbury HC. The use of computerised tomographic imaging in revision mastoid surgery for chronic otitis media. *Am J Otol* 1990;**11**:387–94
10 Swartz JD, Goodman RS, Russel KB. High resolution computed tomography of the middle ear and mastoid. *Radiology* 1983;**148**:461–4
11 Voorhees R, Johnson D, Lufkin R. (1983) High resolution CT scanning for detection of cholesteatoma and complications in the post-operative ear. *Laryngoscope* 1983;**93**:589–95

Address for correspondence:
L. M. Flood, F.R.C.S.,
ENTER,
North Riding Infirmary,
Newport Road,
Middlesbrough TS1 5JE.

Fax: +44(0)1642 231154
E-mail: enter@onyxnet.co.uk

Mr L. Flood takes responsibility for the integrity of the content of the paper.
Competing interests: None declared.