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Labyrinthine fistulae

By J. D. K. DAWES and R. T. WATSON (Newcastle upon Tyne)

WHILE surveying the management of chronic otitis media during a 12-year period from 1965 to 1976, the results of the surgical treatment of 66 labyrinthine fistulae were assessed.

Surgical Anatomy

The topographical sites are listed in Fig. 1 and illustrated in Fig. 2. By far the commonest site is the dome of the lateral semicircular canal.

The relevant surgical anatomy is best appreciated by considering the temporal bone section illustrated in Fig. 3 which passes through the lateral semicircular canal (A), the facial canal (B), the oval window (C), and the promontory (D). The space between the endosteum and the membranous canal at A usually allows safe dissection of a fistula at this site. The vestibule at C and the cochlear duct at D are, in contrast, more vulnerable, although fistulae at these sites may on occasion be safely dissected (see Cases 9 and 10). Erosion of the facial canal (B) must always be anticipated in any chronic ear with a fistula (see Fig. 14).

The horizontal part of the facial canal was exposed in 50 per cent of the lateral canal fistulae; this is twice the expected incidence in operations for cholesteatoma (Dawes, 1976). Exposure of the facial nerve round the oval window may complicate fistulae of the stapedial footplate while fistulae involving the posterior canal may be associated with exposure of the posterior aspect of the vertical portion of the facial nerve, particularly in a small scantily cellular mastoid with a forward lying lateral sinus (Fig. 4).

Occasionally the facial nerve may be involved more proximally:

Case 1

This patient was only referred after a partial facial palsy, which had been present for 3 years, began to progress over the course of 7 to 8 weeks.

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SITE OF THE FISTULA	
Lateral canal alone	51
Superior canal alone	1
Lateral and posterior canals	1
Superior and posterior canals	2
All three canals	2
Vestibule alone	4
Promontory	2
Lateral canal and vestibule	1
Superior canal and vestibule	1
Superior and lateral canals and vestibule	1
Total	66

FIG. 1
Table showing site of fistulae.

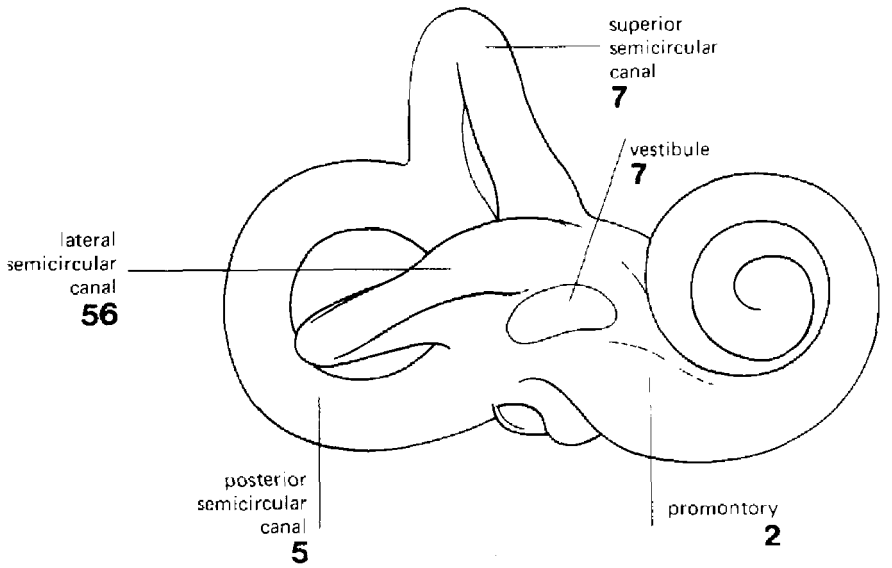


FIG. 2
Diagram showing sites of fistulae.

At operation, the cholesteatoma was found to extend almost to the petrous apex. It had eroded not only the superior canal (see Fig. 5) but also the posterior and lateral canals. The tegmen was almost completely deficient and the posterior fossa dura was also exposed from the genu to the medial end of the internal auditory meatus, and, not surprisingly, there was a temporary leak of cerebrospinal fluid after the operation.

Surgical Pathology

It is the rate of change of the inflammatory process in the ear rather than the size of the fistula which determines whether or not vertigo occurs.

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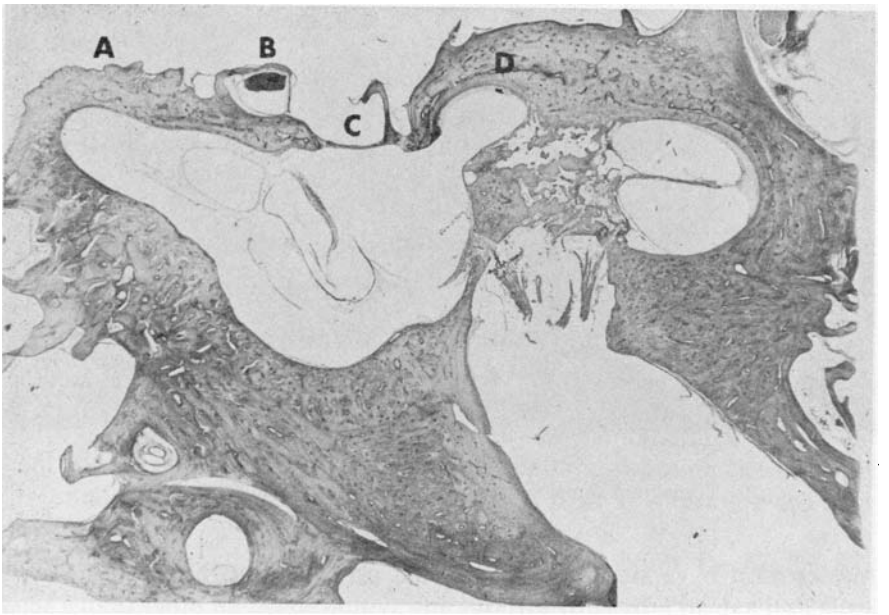


FIG. 3

Section through temporal bone. Note superficial bony erosion over dome of lateral semicircular canal.

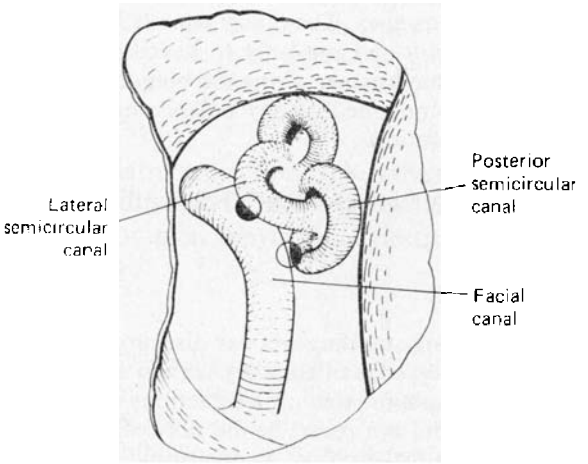


FIG. 4

Diagram showing exposure of the posterior aspect of the vertical part of the facial nerve associated with a fistula of the posterior canal.

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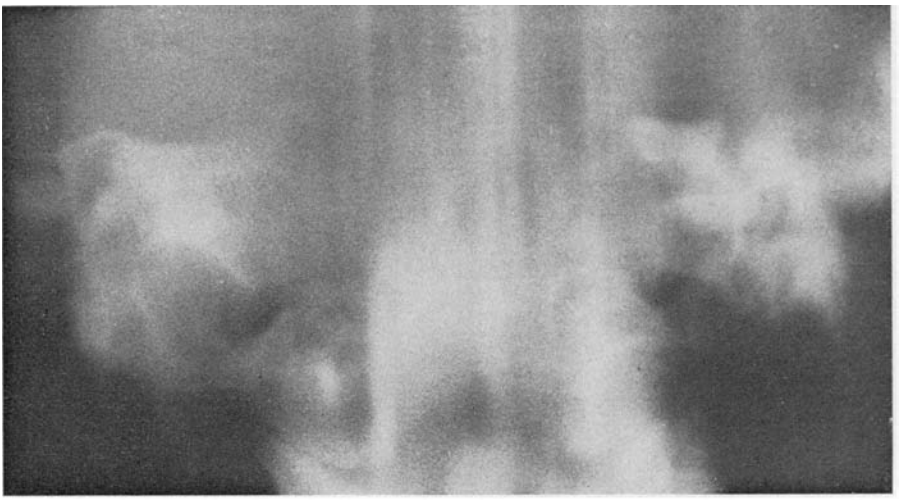


FIG. 5
Tomogram showing fistula of superior semicircular canal.

Slow erosion by a sterile cholesteatoma can insidiously produce a large fistula and a dead labyrinth without any symptoms at all other than a sense of progressive loss of hearing (Dawes, 1971).

Case 2

This patient had a mastoidectomy elsewhere in 1970 for extensive cholesteatoma extending to the petrous apex. The cavity was revised for persistent disease in 1973; cholesteatoma was found not only to have destroyed all three membranous canals but also to have grown along the bony canals to form a cast. At no time had the patient complained of any balance upset, although he had a dead ear at the time of operation.

Vertigo may only occur intermittently, depending on the presence or absence of infection.

Case 3

In 1967 this patient's long-standing wet ear discharged more profusely than usual and he had a sudden episode of rotatory vertigo and vomiting. He sought advice elsewhere and was reassured that nothing serious was amiss. As the vertigo settled spontaneously and did not recur, he did not seek further advice until he awoke 10 years later with a facial palsy. At operation, a large sterile cholesteatoma was dissected off the endosteum of the dome of the lateral semicircular canal. In the absence of active bacterial infection, the exposed labyrinth had been adequately protected from damage for over a decade, the hearing by bone conduction remaining normal in all frequencies. It must be emphasized, however, that such a long symptomless period is very unusual.

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Conversely, the direct spread of infection through pre-existing pathways may dramatically reveal the presence of an unsuspected fistula. If the stapedial footplate has been injured during surgery, for example, or if postoperative infection follows stapedectomy, then sudden infection is likely to be complicated by diffuse labyrinthitis. Similarly an ear which has healed following the spontaneous extrusion of a cholesteatoma may be the site of a symptomless erosion which only becomes apparent when an acute episode of middle-ear infection, perhaps following swimming, or misguided caloric testing (Watson, 1952), leads to diffuse labyrinthitis; the same sequence of events can also occasionally follow surgical fenestration, or the wet method which is still used by some to clean a discharging ear by syringing.

A positive fistula sign may rarely be elicited with an apparently normal middle ear (van Baarle, 1976) but in the presence of chronic middle-ear disease it is a definite, though crude, indication of exposure of the membranous labyrinth. A fistula may occasionally be demonstrated in an outpatient for the first time when using microsuction, although the induced vertigo and nystagmus must be differentiated from a physiological cold caloric response.

When there is total destruction of labyrinthine function, the fistula sign will become negative.

Case 4

In this patient, cholesteatoma had destroyed the dome of the lateral semicircular canal and the resulting low-grade suppurative labyrinthitis caused a 6-week pyrexial systemic illness which was investigated as a pyrexia of unknown origin in a medical ward. The fistula sign was negative by the time the patient arrived in hospital and only when she developed pyogenic meningitis did the otogenic nature of her illness become apparent to the admitting physician (Watson, 1976).

Complete surgical labyrinthectomy, however, may be difficult to achieve in chronic middle-ear disease because of loculation of disease within the labyrinth; incomplete labyrinthine destruction in such cases may result in persisting vertigo.

Case 5

One patient was still dizzy following a surgical labyrinthectomy for chronic middle-ear disease. She had a positive fistula sign, developing vertigo and nystagmus when the area of the round window was touched during aural toilet. The vertigo disappeared following a revision operation to complete the labyrinthine destruction.

Overall we have found the fistula sign to be of limited value in diagnosis, being positive in only 6 of our 66 patients. All of these had a history of balance upset, often when themselves pressing on the tragus during wash-

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ing or shaving. We should like to re-emphasize that most fistulae are not detectable preoperatively (Sheehy and Crabtree, 1973). Less than half of the patients with proven fistulae complained of vertigo, while almost a quarter denied any balance upset at any time. A symptomless fistula was therefore discovered incidentally at operation in as many as 38 of the 66 cases (Fig. 6).

Case 6

This patient presented with a 3-week story of balance upset which proved to be due to a spontaneous oval window fistula. There was massive tympanosclerosis filling the upper part of the tympanum and the whole epitympanum. Although there was no sign of acute inflammation, in view of the recent history of otorrhoea, the ear was explored. As well as the deposits of chalk, glue was present in the mastoid air cells as well as in the tympanum. Tympanosclerosis also involved the stapedial crura and a spontaneous leak of perilymph could be seen coming from a grossly thinned footplate (see Fig. 7). After first disarticulating the incudostapedial joint, the ossicular chain was freed and the oval window was grafted with temporalis fascia. The hearing was beneficially improved after operation, the air-bone gap being closed, but the cochlea had obviously been damaged to some extent as there was no hearing at all in the frequencies above 3,000 Hz.

Whether the labyrinthine endosteum is actually exposed, and whether an actual fistula is found at operation also depends at which stage in the natural history of the disease surgical intervention takes place. Apart from the 66 fistulae described, we have seen 20 other ears during routine chronic ear surgery in which the pathological process had stopped short of actual fistula formation.

In 8 there was only a surface erosion of the dome of the lateral semicircular canal, although in 2 of these the blue line of the underlying membranous canal was already visible through a thin bony covering (Fig. 10a). Such superficial erosions may remain symptomless for long periods and may eventually heal spontaneously, instead of progressing to frank fistula formation. If the healing coincides with long-standing active infection, then normal osteogenesis may be stimulated to produce exuberant new bone formation. This bone is often whiter than normal and tends to

VERTIGO

	No. of patients
Present	28
Denied	15
Not mentioned	23
Positive fistula sign	6

FIG. 6

Table summarizing incidence of vertigo.

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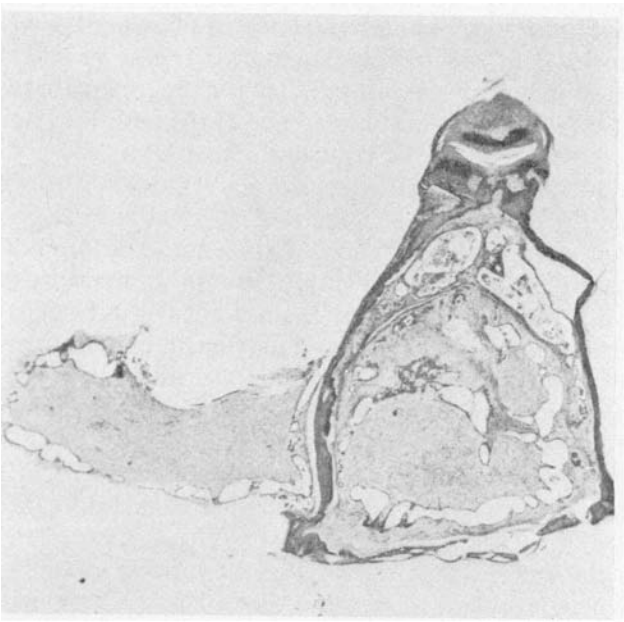


FIG. 7

Section through a stapes similar to Case 6 showing extensive tympanosclerosis, including the stapedial tendon, with gross thinning of the footplate. It is easy to see how a spontaneous leak of perilymph could occur. (H. & E. ×17.)

have a knobbly appearance on the surface of the canal. In 2 ears, this process had been so extensive as to obliterate the aditus and antrum from the dome of the lateral canal to the tegmen. Surgical identification of the landmarks of the medial wall of the middle-ear cleft is especially hazardous in these circumstances as the new bone may be in direct contact with exposed membranous labyrinth or exposed facial nerve. Ten other ears were seen in which one or more of the bony canals, although intact, had been actually skeletonized by cholesteatoma; if these ears had been explored later in the natural history of the disease, the surface area of exposed endosteum is likely to have been very extensive indeed (see Case 2).

The Behaviour of Cholesteatoma Matrix

Almost all labyrinthine fistulae in chronic middle ear disease are associated with cholesteatoma (see Fig. 8).

Number of ears	66
Cholesteatoma	60
Mucosal disease	6

FIG. 8

Table showing incidence of cholesteatoma.

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Cholesteatoma erodes bone by the action of subepithelial granulation tissue (Thomson *et al.*, 1974) (Fig. 9a and b). Therefore unless all vestiges of squamous epithelium are removed, then the residual matrix will continue to erode bone, particularly in the presence of the additional stimulation of bacterial infection. During the course of chronic ear surgery, it does not seem logical to leave squamous epithelium overlying a fistula where it will continue to threaten cochlear function. It is admittedly hazardous to dissect cholesteatoma matrix from a fistula into the promontory of the vestibule if hearing is still present (Fig. 3), but in the majority of fistulae the risk of leaving the matrix behind almost always outweighs the risk of removing it, depending on the skill and judgement of the surgeon (see Cases 9, 10 and 11). If the matrix remains behind over the fistula, then not only is bone healing round the edge of the fistula likely to be inhibited (Shambaugh, 1946), but there remains the same pathological situation which led to urgent surgical exploration in the first place. Palva *et al.* in 1971 warned of just such a case in which labyrinthitis led to a dead ear 3 years after operation.

Fig. 10 demonstrates the behaviour of the various anatomical structures which must be considered when dissecting a fistula. Superficial erosion of the dome of a canal will eventually thin down the bony covering to produce the surgically familiar 'blue line' (a). Once this thin layer of bone disappears, the endosteum becomes directly visible, and a true fistula exists (b). The overlying cholesteatoma matrix present in most cases is usually only loosely applied and can be safely dissected off without damaging the underyling membranous canal. As the fistula enlarges, the matrix will often continue to be loosely applied (c), even when the underlying membranous canal bulges through (d). In the presence of chronic infection, however, there is an increased chance of the membranous canal becoming adherent to the endosteum (e) and sometimes the bared oedematous canal itself will bulge through the bony defect (f); in both these situations the matrix may be adherent. A sterile cholesteatoma may gradually increase in size, destroying all layers to enter the bony canal and slowly grow along it (g) (see Case 1). Occasionally the wall of the membranous canal itself may be destroyed to produce an actual leak of perilymph (h) (Alberti and Dawes, 1961); this only occurred in one lateral canal fistula, although two patients with a cochlear fistula were found to have perilymph leaking from the promontory, and one had perilymph leaking from the vestibule.

Closure of the Fistula

Bone chips (Tos, 1976) or bone dust (Herrmann, 1962) have been advocated to promote osteogenesis round the edge of the fistula. Once active disease has been removed, however, and the ear heals, then defects in the otic capsule can often be expected to close by new bone formation and even become remodelled.

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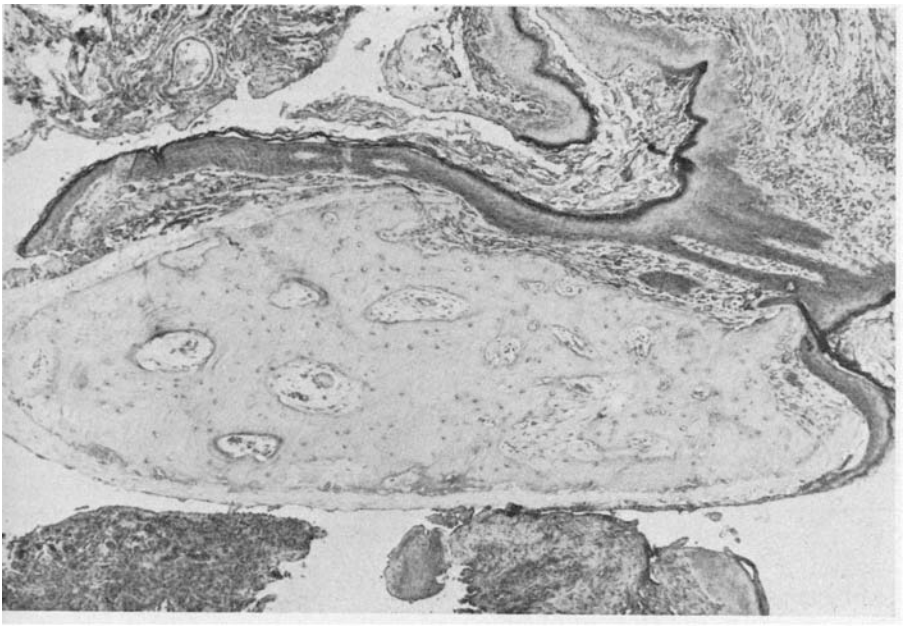
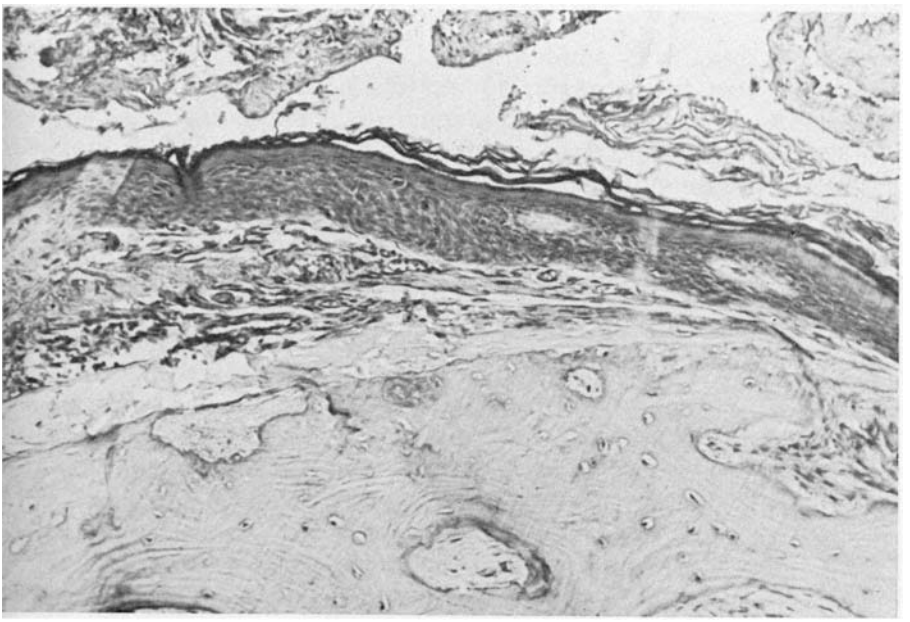


FIG. 9

(a) photomicrograph showing keratinizing squamous epithelium on surface of incus (H. & E. ×55.)



(b) photomicrograph of same ossicle showing subepithial granulation tissue (H. & E. ×130.)

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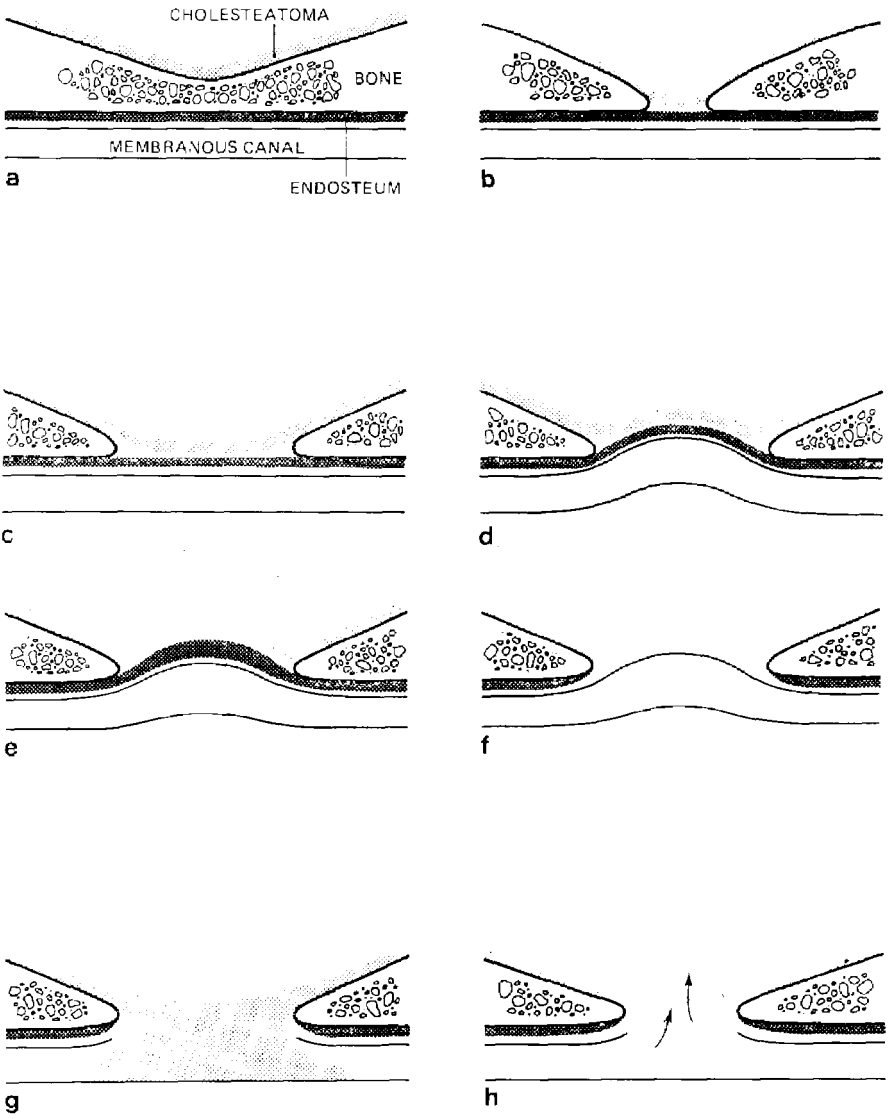


FIG. 10

Diagrams showing the variety of situations which may occur.

(a) superficial erosion

(b) endosteum exposed—matrix loosely applied

(c), (d) matrix still loosely applied

(e) oedematous membranous canal adherent to endosteum

(f) exposed membranous canal

(g) cholesteatoma growing along canal

(h) actual perilymph leak

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Case 7

A 13-year-old boy was operated upon for an extensive cholesteatoma in 1973. Apart from a large fistula into the lateral semicircular canal, the lateral sinus and the jugular bulb were exposed, and squamous epithelium extended down the Eustachian tube. When the cavity was revised for persistent disease 18 months later, the bony covering of the lateral canal was seen not only to be intact but also completely remodelled; the ear healed satisfactorily after the second operation.

Poor hearing following fistula surgery is sometimes blamed on a persisting third window (Leegaard and Röhrt, 1959), but certainly in this series no patient with a healed ear had any long-term balance upset suggestive of an exposed labyrinth.

Detailed descriptions of healed fistulae are rarely available, and the following case is therefore of interest.

Case 8

This patient had a fenestration for a severe conductive deafness caused by ossicular fixation in a mass of tympanosclerosis. The hearing improved dramatically after operation but began to deteriorate after three months. The ear was re-explored 6 years later. The fenestra was found to be closed by exuberant new bone formation on the surface of the lateral canal, and, when it was re-opened, new bone was also found extending into the bony canal to such an extent that the endosteum itself was partially ossified and was wrapped round the membranous canal.

Management

If the hearing loss is already severe or total, or if disease already extends into the labyrinth, there can be no argument that a radical mastoidectomy with complete clearance of disease is essential, with surgical exenteration of the labyrinth in appropriate cases. If useful hearing remains, an open cavity is preferred so that the area of the fistula may be dissected with as wide access as possible, thus minimizing any risk to cochlear function. In almost half our cases, the extent of the disease was such that to ensure adequate clearance it was mandatory to remove the posterior meatal wall and lower the facial ridge (Fig. 11). The operative techniques of epitympanomastoidectomy and tympanomastoidectomy have been described elsewhere (Dawes, 1976).

There is a disconcertingly high incidence of failure to eradicate cholesteatoma in closed types of tympanoplasty (Smyth, 1977), and persistent disease in a closed ear would seem to be particularly dangerous in the presence of a fistula because of the inherent risk to the labyrinth.

Some surgeons have suggested staged surgery, leaving the matrix over the fistula at the first operation and removing it at a second stage some months later. It is argued that the residual cholesteatoma can be removed more safely once active infection has settled, sometimes in the form of a small epithelial pearl. There has even been a report of disappearance of

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EARS WITH EXTENSIVE DISEASE

Structures involved	No. of ears
Petrous apex	1
Internal auditory meatus	2
Carotid canal	1
Jugular bulb	2
Whole of mesotympanum including Eustachian tube	6
Posterior tympanum including sinus tympani	16
Intracranial suppuration	1
Total	29

FIG. 11

Table showing ears with extensive disease.

squamous epithelium at the second operation, possibly due to 'reverse metaplasia' (Law *et al.*, 1975). But for the pathological reasons already discussed, all squamous epithelium should logically be removed from the area of the fistula as a matter of urgency.

Dissecting the Fistula

In all cases the cholesteatoma was carefully dissected from the medial wall of the antrum and aditus, taking care to avoid the use of suction in the region of the semicircular canals, until the anatomy could be clearly seen. It is important to leave the area of the actual fistula till the end of the operation, to use no suction anywhere near it, and to cover it with temporalis fascia immediately after dissection (Palva *et al.*, 1971); this may be a small separate graft or part of the graft used to seal off the mesotympanum. If at all possible, the matrix should be carefully removed from the fistula (Nylen, 1923; Hinsberg, 1926).

The matrix can usually be safely removed from small fistulae (Gacek, 1974) and often from large ones as well (Szpunar, 1976), even if the whole dome of the bony canal has been destroyed and the oedematous membranous canal bulges through (Fig. 10d and e). If the matrix is so adherent that it is not possible to remove it without endangering labyrinthine function (Fig. 10e and f), then the decision must be made to leave it behind (see Case 11). The same may on occasion be true of granulations covering a fistula. If cholesteatoma matrix cannot be safely removed, care should be taken to replace it in such a way that squamous epithelium will not grow into the bony canal (Fig. 12). It is therefore important when dissecting a potential fistula to leave a sufficient area of matrix to overlap the edges of any bony defect, should this become necessary (Fig. 13).

If the stapedial superstructure is destroyed, the intact footplate may need to be dissected and this was done in 10 cases without damaging the cochlea. If the facial nerve is exposed, the nerve sheath may need to be

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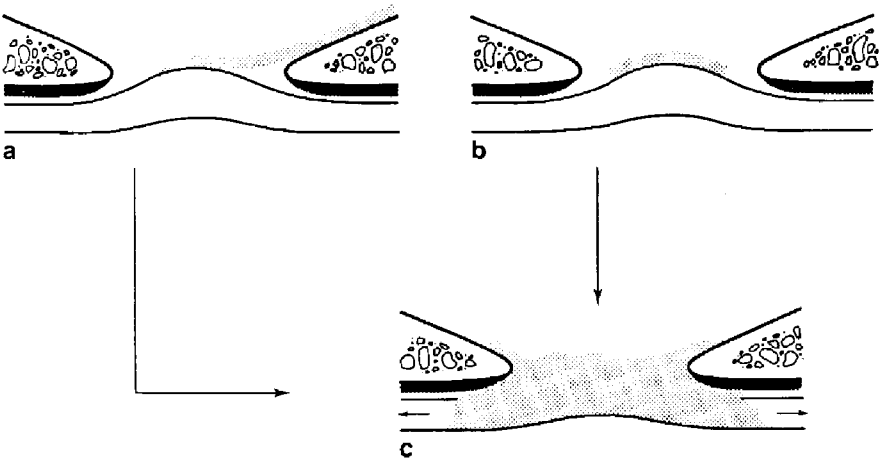


FIG. 12

Diagram showing how squamous epithelium left behind may grow into the bony canal.

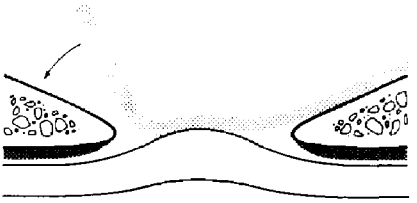


FIG. 13

Diagram showing the ideal method of replacing cholesteatoma matrix if it cannot be safely removed.

State of facial canal		Stapes superstructure destroyed
Facial canal eroded	33	18
Facial canal intact	33	18

FIG. 14

Table showing state of facial canal.

dissected; this was done in 33 ears without causing facial weakness (Fig. 14). Two patients with long-standing palsies showed, not surprisingly, no improvement in facial function, while 3 further patients who had presented with a sudden facial palsy as well as vertigo showed complete recovery of facial function within a few days.

Surgical judgement must on occasion dictate whether the danger of careful dissection is less than the danger of leaving disease behind (see Fig. 3).

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Case 9

This patient, with a long-standing wet ear, had a conductive hearing loss of 50 dB in all frequencies but normal bone conduction. Cholesteatoma had eroded through the dome of the vestibule above the oval window and had also eroded the promontory to such an extent that, although the cochlear duct was not yet exposed, the round window membrane was lying flush with the promontory. Despite the vulnerability of the cochlear duct in this case, careful dissection resulted in a healed, dry ear still with a 50 dB air-bone gap but still with normal bone conduction. The patient was in great danger of losing all hearing in the ear if the matrix had been left behind.

Case 10

This patient was grossly ataxic when first seen with bilateral cholesteatomatous disease and a bilateral high tone sensorineural hearing loss. It was not possible to decide which ear was the site of a fistula. The left ear was explored first and then, because no fistula was found, the right ear was opened. A fistula through the stapedial footplate was carefully dissected out and, when both ears had healed, the pure tone audiogram was unchanged.

Case 11

This patient had had 5 operations elsewhere for a chronically discharging ear, although he had never been dizzy. When the ear was explored recently, there was an L-shaped fistula into the superior semicircular canal, the dome of the vestibule and the lateral semicircular canal, and the cholesteatoma matrix was adherent to the membranous labyrinth (see Fig. 10f). Not only was the facial nerve exposed but squamous epithelium was entering between the perineural sheath and the nerve itself; clearly in these circumstances small fragments of squamous epithelium were of necessity left behind.

Occasionally, even in mucosal disease, the lesion may be so extensive that complete removal is not possible.

Case 12

This patient had an autogenous vein graft myringoplasty performed elsewhere in 1969, and one week later developed vertigo and a dead ear. When the ear was explored 6 months later no cholesteatoma was found but there were extensive granulations extending to the petrous apex, and pus trickled out of a bony defect in the promontory. Because the carotid syphon was exposed and surrounded by granulation tissue and necrotic bone, it was felt unwise to attempt complete removal of the disease. The reason for the aggressive nature of the mucosal disease in this patient has never become clear; the ear has remained unhealed, with a persisting leak of cerebrospinal fluid, intermittent vertigo persists and presumably the cochlea is slowly forming a sequestrum.

Results

The aims of surgery have been to obtain a safe, dry ear, and to preserve what cochlear function remains. The degree of success can be judged from Figs. 15 and 16.

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LONG-TERM STATE OF EARS	
Remaining healed and trouble-free	58
Remaining moist	7
Sequestrating cochlea	1

FIG. 15
Table showing results of surgery.

HEARING RESULTS		
Normal hearing in other ear		37
Dead ear preoperatively		13
Postoperatively	no change	51
	worse—dead ear	2
	- SN loss	3
	beneficial improvement	3
	unknown	7

FIG. 16
Table showing results of surgery.

The hearing was worse after operation in only 5 of the 66 cases. Two developed dead ears; in one, the cholesteatoma filled the lumen of the lateral canal, and in the other all three canals were involved by cholesteatoma, the disease extending as far as the internal auditory meatus. Three other patients developed a high tone sensori-neural hearing loss after operation, but all three had normal hearing in their other ear. In one patient with bilateral fistulae, cochlear function on each side was unchanged following bilateral tympanomastoidectomies with dissection of each fistula. She hears well with a hearing aid.

Conclusion

The importance of attempting to remove all squamous epithelium is emphasized. The advantages of a small trouble-free cavity seem greatly to outweigh the risks inherent in closed techniques. In half the patients the hearing in the opposite ear was normal, so that any form of reconstruction would be unlikely to improve the hearing beneficially, and if the hearing is not socially adequate a hearing aid can always be worn.

Although the 28 patients with vertigo would usually be operated upon as a matter of urgency, it must be remembered that the cochlea of the remaining non-vertiginous 38 patients are no less at risk. This is an added incentive to operate early on all cholesteatomatous ears.

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R. T. Watson,
E.N.T. Dept.,
Royal Halifax Infirmary,
Free School Lane,
Halifax HX1 2YP.

J. D. K. Dawes,
E.N.T. Dept.
Royal Victoria Hospital,
Newcastle upon Tyne NE1 4LP

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