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Traumatic fistulae*

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TEMPORAL bone fractures or penetrating trauma can cause both cerebrospinal fluid (CSF) fistulae accompanying tegmen fractures, and labyrinthine perilymph (PL) fistulae from labyrinth fractures through oval window (OW), round window (RW), cochlear promontory, semicircular canals, or of multiple origin. CSF and PL fistulae can co-exist. Blunt temporal bone trauma without fractures can cause perilymph fistulae, in various locations, singly or combined. Two potential mechanisms, *explosive* and *implosive*, can explain perilymph fistulae due to trauma.

Traumatic events which can produce fistulae are: (1) head trauma; (2) blunt ear trauma; (3) penetrating ear trauma; (4) acoustic/blast trauma; (5) tubotympanic compression trauma; and (6) flying and diving barotrauma.

Basic fistula mechanisms

Surgically visible perilymph fistulae as seen in the middle ear (ME) via OW and RW membrane breaks are accompanied in some cases by invisible intralabyrinthine mixed perilymph-endolymph fistulae due to internal membrane breaks. The latter can occur alone.

Hydrodynamic (CSF) or *aerodynamic* (tubotympanic) routes can be responsible for membrane breaks and they can co-exist in some cases.

Hydrodynamic CSF explosive fistula mechanisms

Labyrinthine perilymph-endolymph systems are linked to arterial, venous and CSF hydrodynamic forces. The crucial CSF-PL relationships function through cochlear aqueduct (C.Aq.) and the internal auditory canal (IAC) neural foramina. Sudden CSF pressure surges to the PL system can cause explosive fistulae.

Variations in patency between perilymph-CSF connections, C.Aq. and IAC are significant (Goodhill, 1971; Goodhill *et al.*, 1973; Goodhill, 1976; Palva, 1970; Palva and Dammert, 1969).

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Note abbreviations used:

C.Aq.	= cochlear aqueduct	OW	= oval window
CSF	= cerebrospinal fluid	PL	= perilymph
EAC	= external auditory canal	RW	= round window
IAC	= internal auditory canal	RWM	= round window membrane
ME	= middle ear	TM	= tympanic membrane

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Explosive fistulae can result from either self-induced diaphragmatic splinting Valsalva forces, environmental barotrauma or from head trauma.

The *C.Aq. route* to *scala tympani* can cause breaks in round window membrane (RWM), and/or in Reissner's, basilar, saccular, utricular or semi-circular canal membranes.

The *IAC route* to *scala vestibuli* can cause breaks in oval window (OW) ligament and/or similar internal labyrinthine membrane breaks producing explosive fistulae resulting in hearing loss, vertigo and tinnitus.

Aerodynamic implosive fistula mechanisms

Aerodynamic pressure surges via the tubotympanic system communicate with RWM and OW footplate ligament areas as a route for *implosive fistulae*. Self-induced forceful Eustachian tube inflation forces or tubotympanic Valsalva forces in flying and diving can cause implosive round window and/or oval window fistulae, with chain reaction internal labyrinth membrane breaks producing implosive fistulae with resulting hearing loss, vertigo and tinnitus.

1. Fistulae due to head trauma

Both closed and open head injuries can produce PL fistulae, a number of which have been reported (Althaus, 1977; Fee, 1968; Fernandes, 1977; Healy *et al.*, 1971; Schuknecht *et al.*, 1951). If fractures occur they may also result in CSF fistulae, via explosive and/or implosive routes. Three illustrative cases provide examples.

Case report #1: A 21-year-old woman with a severe head injury following a car accident was seen one year post-injury with dizziness and left hearing loss. A malleal-manubrial fracture in an intact TM was accompanied by mixed hearing loss, vestibular paresis, and spontaneous nystagmus. At surgery there was partial incudostapedial joint separation, footplate fracture and OW fistula, which were repaired with 75 per cent air-bone gap closure and no further dizziness. The mechanism was probably implosive.

Case report #2: A 35-year-old woman received a head injury in a car accident followed by dizziness and left hearing loss. There were no fractures. Examination showed 75 dB left sensorineural hearing loss and left canal paresis. At surgery both OW and RW fistulae were repaired with improvement in hearing (to the 30 dB level) and in balance.

Case report #3: A 58-year-old woman with long standing conductive (55 dB) hearing loss and right 'secretory' otitis had normal standard x-rays. Tympanocentesis yielded clear sterile fluid under moderate pressure. At tympanotomy this clear fluid rapidly refilled following suction. There was a small anterior OW perilymph fistula and a tegmen fracture with a CSF fistula. At a second stage transmastoid procedure both fistulae were sealed with

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temporalis fascia. Subsequently she recalled a relatively asymptomatic car accident head injury several years before. The mechanism was explosive.

2. Fistulae due to blunt ear trauma

Blunt blows to the auricle can produce PL fistulae. Open hand slaps to the auricle which usually produce large tympanic membrane (TM) perforations can also produce PL fistulae. Two illustrative cases provide examples.

Case report #1: A 15-year-old boy was struck in the left auricle by a baseball, followed by immediate dizziness and left hearing loss. When examined 16 days later, there were severe left mixed hearing loss, positional nystagmus and left canal paresis. At tympanotomy a fractured footplate with OW fistula was repaired, followed by rapid cessation of vertigo but no hearing improvement.

Case report #2: A 28-year-old woman was slapped on the right ear, with immediate otalgia, hearing loss and vertigo. When seen 10 days later there was a large central TM perforation, positional nystagmus, mild canal paresis, and mixed right hearing loss. An OW fistula in the anterior pericrural region was repaired along with myringoplasty, followed by relief of vertigo and improved hearing.

The mechanisms in both cases were implosive.

3. Fistulae due to penetrating ear trauma

Slag injuries, gunshot wounds and iatrogenic injuries in attempts to remove EAC foreign bodies are some of the causes of penetrating PL fistulae accompanying TM-ossicular injuries. OW, RW, and intralabyrinthine lesions frequently occur due to labyrinthine capsule fractures. Two illustrative cases provide examples.

Case report #1: A 5-year-old child with a glass bead in the right ear was examined 7 days after several unsuccessful attempts at removal were made. A 75 dB mixed hearing loss was present, the EAC was lacerated and filled with dried blood. A modified endaural incision revealed a torn TM, with a bead wedged between partially dislocated incus and stapes. Following removal of the bead, an OW fistula accompanying a footplate fracture was noted. Incudostapedial repair, fistula repair, and myringoplasty were accomplished. There was a persistent 35 dB hearing loss.

Case report #2: A 52-year-old welder was examined one year following a slag injury to the left ear with complaints of dizziness and hearing loss. There was almost total TM absence, with many metallic fragments embedded in the promontory and in other portions of the ME. A mixed hearing loss was accompanied by spontaneous nystagmus and marked canal paresis, as demonstrated by the dry calorization ENG technique (Eviatar and Goodhill, 1968). At surgery there were OW and RW fistulae, and a promontory fracture fistula. Slag and

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ossicular remnants were removed and the fistula sealed. Tympanoplastic repair was postponed. There was marked improvement in vertigo but hearing remained unchanged.

4. Fistulae due to acoustic/blast trauma

High intensity acute acoustic trauma (not related to ordinary noise-induced hearing loss) and/or blast from explosives can produce PL fistulae with or without TM ruptures.

Case report: A 25-year-old woman with no previous exposure to gunfire fired a single shot from a magnum revolver held in her right hand. There was immediate severe right otalgia, tinnitus and violent dizziness. When examined in our clinic one month later she was totally deaf in the right ear, and very dizzy. There was spontaneous nystagmus, the right TM was intact and thickened, with suggestion of ME fluid. At tympanotomy, an extensive friable fibrous network surrounded OW and RW fibrous compartments, all filled with perilymph. Following repair of fistulae there was immediate relief of dizziness, marked diminution of tinnitus but no return of hearing.

5. Fistulae due to tubotympanic compression trauma

Forced 'tubal clearing' done voluntarily by violent closed nasal Valsalva inflation can produce perilymph fistulae.

Case report: A professional flyer with a long history of nasal allergy attempted to clear a blocked right ear during a flight which he was piloting. He forcibly attempted closed nasal Valsalva inflation and noted sudden right tinnitus, hearing loss and dizziness. Surgical exploration 8 weeks later showed partial I-S joint dislocation and an OW fistula, both of which were repaired. The vertigo disappeared but there was only moderate gain in hearing.

6. Fistulae due to flying and diving barotrauma

Barotrauma forces in aviation and diving are major causes of PL fistulae, which already have been discussed. We have operated on a number of such patients with sudden hearing loss and vertigo, and have repaired OW, RW and combined fistulae.

Conclusions

CSF fistulae following TB fractures have been recognized for some time. More recently PL fistulae following a variety of temporal bone traumatic events have been demonstrated beyond question. Causative mechanisms are reasonably clear. There is, however, a need for more definitive diagnostic methods.

There are many current questions among which are:

1. Is the round window the primary location?

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NO. Both RW and OW lesions can occur together or singly. There are more *OW fistulae than RW fistulae.*

2. What does a fistulae look like? Is there an actual visible hole in the RW membrane or in the footplate region?
   NO. A hole is very rare. It is usually a marginal membrane tear in either the OW or the RW.
3. Does perilymph escape as a rapidly flowing stream?
   NO. It is a slow refilling of clear fluid in either or both niches.
4. Is surgery always necessary and urgent?
   NO.
5. What are the criteria for surgical exploration?

The criteria for surgical exploration are persistent audio-vestibular symptoms in a patient with a history of temporal bone trauma which do not subside on a period of enforced bed rest, preferably in hospital, with head elevated 30° for 48–72 hours. Daily interval audiovestibular examinations are made.

If no significant improvement is noted after 72 hours of bed rest, surgical exploration is considered.

Surgical technique details

1. Fistulae are almost always at least partly surrounded by fibrous bands requiring microdissection.

2. Following delicate dissection of fibrous compartments in the two window areas very gentle fine suction in anterior OW area and in RW area is necessary. The extent of fluid leaks may vary from a 'gusher' to a very minute, slow but persistent fluid flow, which may be increased by gentle incudostapedial joint palpation.

3. Jugular compression may give improved visualization by increasing PL flow.

4. The RWM may not be completely visualized and an actual hole is seen only rarely. If persistent PL flow is seen from the region of the RWM it is adequate to pack the area after denuding endosteum from the superior RW niche region to furnish a base for anchorage of the tragal perichondrium or temporalis fascia graft. Gelfoam is not a seal.

5. I do not drill away promontory bone overhang in the RW niche.

6. In spite of careful persistent searches there may be no fistula. Obviously this concludes the procedure.

Labyrinthine concussion and inner ear barotrauma are complex concepts. CSF-PL pressure increases can damage labyrinthine function by hypoxia alone without obvious membrane breaks. However, fistula possibilities must also be considered.

I close with two hopes (1) that clinical awareness of possible PL fistulae in temporal bone trauma will increase and (2) that such awareness

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will *not necessarily* lead to a dramatic increase in urgent surgery for TB trauma patients with relatively minor audiovestibular changes, many of which may be temporary and self-limited. A trial with bed rest in head elevated position should precede surgery decisions.

We will eagerly await some final answers to these problems from the temporal bone pathologists.

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