

Paparella: Volume II: Otology and Neuro-Otology

Section 3: Diseases of the Ear

Part 4: Inner Ear

Chapter 42: Labyrinthitis

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The term labyrinthitis, or otitis interna, is applied to a group of inflammatory conditions of the inner ear implicating either one or both of the labyrinthine compartments. These conditions can be grouped into two categories: infective and noninfective. In most labyrinthitic conditions, the clinical picture is similar, in part comprising disequilibrium and diminished hearing. However, the recognition of the origin of these conditions, their nature, and their differential diagnosis is an essential precursor to treatment that in some cases can effect a cure and preserve hearing.

Classification

The following simple and comprehensive classification encompasses the various inflammatory reactions of the labyrinth on the etiologic basis.

A. Infective types: Pathogenic organisms may be recovered from the labyrinth during the active phase of the disease.

1. Bacterial labyrinthitis
 - a. Purulent labyrinthitis
 - b. Paralabyrinthitis
2. Viral labyrinthitis
3. Syphilitic labyrinthitis
4. Protozoal labyrinthitis
5. Fungal labyrinthitis

B. Noninfective types: During the full-blown disease, the inner ear is usually sterile.

1. Toxic labyrinthitis
2. Autoimmune labyrinthitis
3. Labyrinthitis ossificans.

Purulent Labyrinthitis (Suppurative Labyrinthitis)

Suppurative labyrinthitis is still a clinically significant entity in otologic practice and is by far the most serious inflammatory reaction of the inner ear. Its occurrence is almost invariably associated with profound and permanent loss of both auditory and vestibular functions.

Etiology

Suppurative labyrinthitis arises when pyogenic bacteria invade the inner ear. This may occur with either acute or chronic infection of the middle ear, with meningitis, and much less frequently with systemic infections or septicemia.

Tympanogenic labyrinthitis results from passage of infective pathogens from the middle ear cleft to the labyrinth through a pathologic or surgical fistula or across one of the two labyrinthine fenestrae. In chronic otitis media with cholesteatoma, labyrinthitis develops typically by erosion of the bony horizontal semicircular canal, which constructs a pathologic fistula (perilabyrinthitis or paralabyrinthitis). In acute otitis media, the pathogenic bacteria may invade the secondary tympanic membrane of the round window or the annular ligament of the oval window. The round window is probably more important than the oval window in this regard (Paparella and Sugiura, 1967). The round window membrane is often thin and more susceptible to invasion in the nonchronically infected ear (Schachern et al, 1987b). Electrophysiologic evidence of cochlear losses in the basal turn has been described in animals with experimentally induced acute otitis media (Paparella et al, 1984), and sensorineural hearing loss in the high frequencies has been reported in patients with chronic and acute suppurative otitis media (Paparella et al, 1972; English et al, 18973; Moore and Best, 1980; Aviel and Ostfeld, 1982; Walby et al, 1983; Paparella et al, 1984).

The inadvertent creation of *fistulae during surgery* on the middle ear may result in iatrogenic purulent labyrinthitis. Examples include accidental fenestration of the horizontal semicircular canal during mastoidectomy, septic mishaps in stapedial surgery for otosclerosis, inadvertent dislocation or subluxation of the stapes during tympanoplasty, and uncovering of an unexpected cochlear fistula during aural polypectomy. Other labyrinthine fistulae may be caused by tumors, fracture of the temporal bone, and penetrating trauma. The causative organisms are those associated with acute and chronic ear infections: beta-hemolytic *Streptococcus*, *Pneumococcus*, *Haemophilus*, *Proteus*, *Pseudomonas*, and *Staphylococcus* species.

Meningogenic labyrinthitis is a major etiologic factor in profound deafness among pediatric patients. The incidence of postmeningitic deafness ranges from as low as 3 per cent to as high as 25 per cent (Dodge and Swartz, 1965). In most cases, the deafness is bilateral and moderate to severe (Baldwin et al, 1985). The bacterial organisms most commonly associated with generalized meningitis having sensorineural hearing loss as a sequela are *Haemophilus influenzae* and *Streptococcus pneumoniae* (Muñoz et al, 1983).

The incidence of influenzal meningitis has increased over the last three decades (Michael, 1971). This has been conceivably associated with a similar increase in meningogenic influenzal labyrinthitis. Paparella and coworkers (1986) reported the pathologic findings in 10 temporal bones from five infants who had died of *H. influenza* meningitis. Purulent labyrinthitis was evident in all of the 10 temporal bones. Immense numbers of inflammatory cells filled the cochlear aqueduct, and many infiltrated the modiolar spaces. The short survival period after onset of meningitis (less than 3 days for four infants) demonstrates how quickly and readily infection

spreads to the labyrinth. The primary pathways for transmission of infection in meningogenic labyrinthitis are the cochlear aqueduct and the internal auditory canal through perineural and perivascular spaces of the modiolus.

Hematogenic labyrinthitis is the least common and least documented form of suppurative labyrinthitis. It assumes the blood-borne transmission of pyogenic pathogens from distant or systemic infection or from adjacent areas of infection, as in meningitis encephalitis or brain abscess. It is conceivable that septic emboli may obstruct terminal labyrinthine arteries, causing severe labyrinthine damage from ischemia as well as a direct inflammatory reaction.

Pathogenesis

Recent studies have shown that the inner ear possesses its own immunologic system (Harris, 1984). These defense mechanisms are activated as the inner ear is antigenically challenged by infecting particles. In response, the inner ear reacts by producing specific antibodies, mobilizing inflammatory cells to the infected site, and forming a richly fibrinous exudate. The fibrinous exudate is meant to isolate the site of infection from the rest of the labyrinthine spaces. This explains why the pyogenic reaction in labyrinthitis tends to be confined to the scala tympani of the basal cochlear turn adjacent to the round window and opening of the cochlear aqueduct, which are the common portals of infection of the inner ear; it also explains the basal distribution of the bony and fibrous tissue in labyrinthitis ossificans, which is the healing stage of the labyrinthine infection. Failure to localize the infection results in a generalized destructive form of purulent labyrinthitis. Eventually, the inner ear attempts to contain the pyogenic infection by fibroblastic proliferation, by formation of granulation tissue, and ultimately by genesis of fibro-osseous tissue within the inner ear.

Pathology

Most of the primary pathways of infection from the middle ear and meninges to the inner ear lead to the perilymphatic spaces. Therefore, suppurative labyrinthitis, whether tympanogenic or meningogenic, is primarily perilymphatic labyrinthitis, with eventual involvement of the endolymphatic spaces in the more severe forms. Hematogenic labyrinthitis, however, is presumably an *endolymphatic* labyrinthitis in which septic emboli lodge in the more vascular areas of the inner ear (such as the stria vascularis) more closely related to the endolymphatic space.

It is convenient to assign four stages to the pathologic events in the inner ear during a typical episode of purulent labyrinthitis.

1. *Serous stage (serofibrinous or irritative stage)*. Production of serofibrinous exudate rich in specific immunoglobulins is the earliest reaction of the inner ear to invading pathogens. Only a few pus cells and bacteria may be present, localized to sites of entry. In this stage, a recoverable diminution of function in the inner ear results from biochemical alteration of labyrinthine fluids and possibly from hindering by fibrinous exudate of the propagation of sound

waves along the cochlear spirals. The disease may be arrested at this stage, depending on the virulence and dose of infecting pathogens, on local immune mechanisms of the inner ear, and on the efficacy and timing of antibacterial treatment provided.

2. *Purulent stage (acute or manifest stage)*. In the acute stage, intra- and extracellular bacteria and leukocytes fill the perilymphatic space, along with a serofibrinous exudate that will stain pink with eosin, indicating an increased protein content, and with other chemical changes in the perilymph that in some cases probably predispose to endolymphatic hydrops. Other pathologic changes in the inner ear include vasodilatation, thrombosis or extravasation of modiolar blood vessels, and severe degenerative and necrotic changes of the end-organs.

3. *Fibrinous stage (chronic, latent, or healing stage)*. The third stage is characterized by fibroblastic proliferation within perilymphatic spaces. Although fibroblasts predominate, small capillaries are present and this tissue may be termed granulation tissue. Pus cells can still be seen. This stage may begin 2 weeks after the onset of infection.

4. *Osseous stage (healed, compensated, fibro-osseous, or sclerotic stage - labyrinthitis ossificans)*. Bone formation characterizes this stage and is first seen to occur in the anterior labyrinth in the perilymphatic spaces of the basal cochlear turn. Eventually these changes become widespread and may involve all parts of the inner ear. In animals, early formation of bone may occur after 2 months. Bone forms several months after acute labyrinthitis in humans. Many years are required before complete labyrinthitis ossificans develops (Paparella and Sugiura, 1967).

Depending on the site and severity of the inflammatory process, these stages often overlap one another. In general, a brief serous stage precedes the purulent stage. The two stages overlap before they proceed to the fibrous and osseous stages. Pathologic changes in the purulent and fibrous stage are not often seen concurrently, whereas the fibrous stage and osseous stage are usually present together. The disease can be aborted in the serous stage, and the condition may be restored to normal. However, once the purulent stage is reached, the disease progresses all the way to the osseous stage, with permanent loss of function of the inner ear.

Clinical Picture

Serous (Irritative Stage)

This brief, stormy stage is characterized by a variable degree of cochlear deafness, severe vertigo, and nausea and vomiting. There is nystagmus beating toward the affected ear until generalized suppuration and destruction of the labyrinth take place, at which time it reverses toward the normal ear. The extent and rapidity of destruction determine the point at which the nystagmus will reverse. Reversal usually takes place within the first day.

Purulent (Manifest Stage)

In the purulent stage, the patient is violently ill, with profound hearing loss, incapacitating vertigo, and nausea and vomiting. The patient develops spontaneous nystagmus toward the unaffected ear, tends to fall to the affected side, and past-points to the same side. Any movement aggravates the vertigo, so the patient usually lies quietly with the eyes closed, typically lying curled in bed with the affected ear uppermost. In this position, to look up is to gaze in the direction of the slow component of the nystagmus, and nystagmus is decreased. Fever usually denotes the infective nature of the disease. Labyrinthine manifestations ensuing in the presence of acute or chronic otitis media or meningitis should be strongly suspected to represent a secondary bacterial labyrinthitis.

The diagnosis is made clinically, usually retrospectively when there is failure to recover function in the inner ear. Caloric investigation is contraindicated, as it may spread the infection by movement of the intralabyrinthine fluid. Modification in the clinical picture may be encountered in meningogenic and bilateral labyrinthitis in which the bilateral and simultaneous labyrinthine failure results in cancellation of or amelioration of vestibular manifestations. The picture is further blurred by the superimposed meningeal or cerebellar manifestations.

Fibrous (Chronic or Latent) Stage

This period follows the initial, stormy, acute stage and lasts from a few weeks to a few months. The labyrinth has been completely destroyed, and deafness is complete. Incapacitating vertigo has disappeared, but a milder vestibular upset and positional vertigo may persist. If compensation is slow, as in older persons, vestibular difficulty may be more troublesome.

Healed (Osseous) Stage

This stage commences after 2 to 3 months, and many years are required before complete ossification occurs in the membranous labyrinth. By this time, the patient has fully compensated, the only findings being loss of auditory and vestibular functions as determined by hearing and caloric testing. Occasionally, positional dizziness persists in some patients for some months during this stage. If bilateral involvement (meningogenic labyrinthitis) has occurred, there will be difficulty in walking, especially in the dark or on a soft surface.

Treatment

Treatment must aim urgently at these broad general lines: (1) control of labyrinthine infection, (2) control of the source of infection (otitis media or meningitis), (3) prevention of the possible complications, and (4) symptomatic treatment.

Control of Labyrinthine Infection

Intensive antibacterial therapy is started in order to limit infection of the endolymph. It is also hoped that by limiting infection to the perilymph, the end-organs surrounded by endolymph may be preserved. Heavy doses of intravenous penicillin (2 to 3 million units per day) and sulfadiazine (to a total of 6 gm per day) are administered promptly. Other antibiotics may be used, depending on sensitivity studies of cultures obtained from the infecting source (such as cerebrospinal fluid, discharge from the middle ear, or blood).

Control of Source of Infection

Meningitis. Meningitis is usually controlled by systemic administration of penicillin and sulfadiazine. Intrathecal injection of penicillin is recommended by some, in cases in which the condition is desperate. Usually the same antibacterial treatment disposes of both meningeal and labyrinthine infections.

Acute Otitis Media. The treatment is primarily medical. Again, penicillin and sulfadiazine may be the drugs of choice. Myringotomy should be performed if the drumhead is intact or has a small or malsituated perforation insufficient for adequate drainage of the middle ear.

Chronic Otitis Media. Mastoid surgery under antibiotic cover should be urgently performed to alleviate the source of infection in the inner ear. Classically, a radical mastoidectomy is done to safely clear the cleft of cholesteatoma, granulations, and any sort of intractably pathologic tissue. We also graft the round window membranes in these cases to deter any further passage of infection. Indications for and timing of an operation to facilitate labyrinthine drainage are still controversial. We advocate deferring such an operation until the results of antibacterial and surgical treatment are assessed. Thus, the main indication for draining the labyrinth is the emergence of meningeal manifestations despite adequate antibiotic therapy and adequate clearance of the cleft by excisive surgery. There are many modifications of this surgical operation on the labyrinth, but the main principle is that all aspects of the labyrinth should be drained. The bony promontory between the oval and round window is removed, allowing for drainage from the basal turn of the cochlea and from the vestibule. The semicircular canals are entirely removed and the vestibule is drained from above and behind.

Prevention of Possible Complications

Of all the tissues of the body, the central nervous system offers the least resistance to infection, and as the perilymphatic and subarachnoid spaces are connected in such an open way as to permit the passage of particulate matter from either side to the other, labyrinthine infection carries a potential danger of causing serious intracranial complications, of which the most common is septic meningitis. Prevention is attempted by the institution of heavy antibiotic therapy and by surgically draining the labyrinth once there are early manifestations of meningeal irritation.

Symptomatic Treatment

The patient is hospitalized and limited to bed rest. The head is immobilized with the affected ear uppermost. Antivertiginous and antiemetic drugs help to control the vestibular symptoms.

Circumscribed Labyrinthitis (Paralabyrinthitis, Perilabyrinthitis, Labyrinthine Fistula)

This condition, as its name implies, is an inflammation restricted to a discrete portion of the bony labyrinth and endosteum, without involvement of the membranous labyrinth.

Etiology

The most common cause of pathologic fistulae of the labyrinth is cholesteatoma. The most common site is the horizontal semicircular canal; however, fistulae of the cochlear or vestibular walls do sometimes occur. Granulation tissue and cholesterol granuloma have a tendency to erode and may create a fistula in the absence of a cholesteatoma. The mechanism involved is by hyperemic decalcification of bone or rarefying osteitis. Other causes include congenital syphilis and tumors of the middle ear (carcinoma and glomus jugulare). Tumors are more likely to erode the cochlear or vestibular bony walls than to enter the horizontal canal.

Clinical Picture

Absence of spontaneous nystagmus in perilabyrinthitis is due to absence of inflammation of the membranous labyrinth. However, due to its exposure, the membranous labyrinth becomes increasingly sensitive to exogenous stimulation including pressure and thermal changes and occasionally loud acoustic stimuli (Tullio phenomenon). The patient complains of transient vertigo, which can be induced by syringing the ear, pushing on the tragus, autoinflation of Valsalva's maneuver, pneumatic massage by Siegle's otoscope, or manipulation of an aural polyp. The vertigo is often mild and brief and is not accompanied by nausea or vomiting, nor is it violent enough to result in a fall. The presence of a fistula is demonstrated by the fistula test in which the pressure in the external auditory canal is altered by means of a pneumatic (Siegle's) otoscope or Politzer's bag or by pressing on the tragus. A positive pressure causes an ampullopetal flow on endolymph in the lateral semicircular canal, increases the tonus of the canal, and produces a conjugate deviation of both eyes to the unaffected side, with a nystagmus toward the affected ear. A negative pressure has the reverse effect. Vertigo in the absence of nystagmus is still predictive of a fistula (the fistula sign), although it is not as strongly positive.

Complications

In the presence of a labyrinthine fistula, suppurative labyrinthitis may be precipitated by acute exacerbation of otitis media or by the purposeful or accidental uncovering of a fistula or the removal of a cholesteatomatous matrix or pulling on an aural polyp. In progressive, chronic

aural disease, the labyrinth may be invaded through the fistular site by granulation tissue, fibrous tissue, and on rare occasions squamous epithelium, resulting in a keratoma of the inner ear (Schuknecht, 1974).

Treatment

A positive fistula test in the presence of chronic disease in the middle ear is an indication for surgical exploration of the tympanomastoid, and the bony covering of the labyrinth should be carefully examined. Management of a cholesteatomatous matrix overlying a fistula is still controversial (Smyth, 1980). The sensorineural hearing loss is not significantly different, whether the cholesteatomatous membrane is removed or preserved over a fistula in the horizontal canal (Sheehy, 1978).

Because the techniques employing a closed mastoid cavity and obliteration are frequently used, it is considered a sound policy to remove the matrix in such cases. Under adequate magnification and illumination, the membrane is carefully lifted off. The fistula should be immediately sealed off with bone dust and covered by a fascial graft.

On the other hand, cleaning a cochlear fistula carries a higher risk of loss of hearing. In this case, and for fistulae of the horizontal canal in the only-hearing ear, an open technique with preservation of the matrix and exteriorization of the disease is preferred.

Viral Labyrinthitis

Viral labyrinthitis may complicate the course of systemic viral infections such as measles, mumps, influenza, and chickenpox. Mumps often causes unilateral labyrinthitis and deafness, whereas labyrinthitis from measles is usually bilateral. Viral labyrinthitis may also occur in the absence of systemic viral disease, in which case it would present sudden idiopathic hearing loss. A third clinical presentation is congenital deafness resulting from fetal labyrinthine involvement with maternal viral infection. An example of this latter presentation is the hearing loss associated with congenital rubella and congenital cytomegalic inclusion disease.

To date, the pathogenesis of viral infection of the inner ear has not been clearly elucidated, despite the magnitude of the clinical problem. Although serologic studies can establish that a patient is infected with a particular virus, establishing optimal proof that the virus is the cause of the labyrinthitis would entail (1) association of the virus with the clinical syndrome, (2) isolation of the suspected virus from the inner ear, and (3) subsequent demonstration that the virus can cause similar disease in experimental animals (Davis and Johnsson, 1983). Only cytomegalovirus (Davis et al, 1979) and mumps virus (Westmore et al, 1979) have been isolated from the perilymph of affected ears. When it is not possible to isolate the virus within the labyrinthine fluids, identification of viral pathology within the tissue is almost as good (Davis and Johnsson, 1983).

The pathologic features attributed to viral labyrinthitis have been concluded upon largely from studies of human temporal bones, which have shown that deafness invariably resulted from endolymphatic labyrinthitis involving the organ of Corti, stria vascularis, and tectorial membrane and that the pathologic changes in all types of virally induced hearing loss are remarkably similar (Lindsay and Hemenway, 1954; Lindsay et al, 1960). These findings are in opposition to those in recent experimental work with animal models of viral labyrinthitis, which studies have shown different affinities of cells in the inner ear to each virus, indicating that there is no consistent pattern in viral labyrinthitis (Davis and Johnson, 1976; Tanaka et al, 1984). The possibility of meningogenic viral perilymphatic labyrinthitis was first suggested by Paparella and Sugiura (1967). Further evidence of this type in experimental animals was provided by Shimokata and colleagues (1977). It is possible, however, that differences among species account for the patterns of involvement being different in human temporal bones.

Viral labyrinthitis may result in transient vestibular symptoms, but deafness develops quickly and persists as a permanent handicap. Manifestations of viral diseases of the inner ear are more fully discussed in Volume I, Chapter 25. Prevention of infection by vaccination is effective in reducing hearing loss of viral etiology. Treatment is symptomatic, supportive, and nonspecific and includes sedation, antivertiginous drugs, and reassurance.

Syphilitic Labyrinthitis (Luetic Labyrinthitis)

Labyrinthine involvement occurs with both acquired and congenital syphilis. The pathologic lesions of the inner ear are identical in the two types and result in a high incidence of hearing loss. Two pathologic patterns of involvement have been identified. The first is meningo-neuro-labyrinthitis occurring in early congenital and in secondary and tertiary acquired syphilis; the second is syphilitic osteitis and fistulization of the labyrinthine bony wall, which occurs during the late congenital and tertiary acquired stage of syphilis (see Chap 40, Vol I).

Protozoal Labyrinthitis

A pathologic relationship of the protozoon *Toxoplasma gondii* with the inner ear has been suggested on the basis of clinical observation, particularly regarding the association of congenital toxoplasmosis and deafness. Falser (1981) induced experimental infection of the inner ear of the guinea pig with intracochlear injection of this protozoon. Conclusive histologic evidence, however, is still lacking.

Fungal Labyrinthitis

An alarming increase in fungal infections has been associated with widespread use of broad-spectrum antibiotics, steroids, and chemotherapy. There has been a similar increase in fungal labyrinthitis, indicated by the increase in reported cases (Igarashi et al, 1975; McGill, 1978; Meyerhoff et al, 1979; Gussen and Canalis, 1982). The mycoses reported to invade the inner ear include *Candida*, *Mucor*, *Cryptococcus*, and *Blastomyces* species. Certain patients are critically prone to contracting serious fungal infections; these include those who are severely

diabetic, leukemic, or terminally debilitated as well as those with organ transplants. Conclusive examples of involvement of the inner ear with fungal disease via tympanogenic, meningogenic, and hematogenic routes have been demonstrated (Meyerhoff et al, 1979).

Pathologic findings in the inner ear vary greatly in reported cases. However, in many of them, fungal elements had invaded the modiolar perineural and perivascular spaces and the perilymphatic spaces. A variable extent of damage to the organ of Corti was noticed in most cochleae, and in some of them destruction of the spiral ligament, stria vascularis, or cells of the spiral ganglion was evident. Vasodilatation, labyrinthine hemorrhage, eosinophilic precipitate in the perilymph, and invasion by granulation tissue were also reported.

Treatment is initiated with systemic administration of antifungal drugs. Amphotericin B (Fungizone) is given intravenously on alternate days over extended periods of time for a maximum total of 1.5 to 5 gm. Attention should be paid to watching for the nephrotoxic and myelodepressive effects of the drug.

Toxic Labyrinthitis (Serous, Serofibrinous, Irritative, Sterile Labyrinthitis)

Serous labyrinthitis is a sterile inflammatory condition of the inner ear, induced by chemical or toxic irritation of the membranous labyrinth. The irritative agents are bacterial toxins, constituents, or products; mediators of bioproducts of inflammatory reactions; or metabolic products of neoplastic growths in the middle ear, temporal bone, or internal auditory canal. The irritating agents are conveyed from the middle ear to the inner ear across the two labyrinthine windows, and from the cranial cavity via the internal auditory canal and cochlear aqueduct.

Pathology

The perilymphatic spaces and, to a lesser extent, the endolymphatic spaces are filled with an eosinophilic sero-proteinoid, fibrinous, or fine granular material. The inflammatory reaction has barely any effect on the neuroepithelium. Mild endolymphatic hydrops may be encountered. A mild or severe reversible hearing loss is present and is attributable to (1) the presence of thick fibrinous or proteinoid material hindering the propagation of sound waves along the cochlear spirals, (2) the biochemical alteration of inner ear fluids, and (3) the endolymphatic hydrops that results from impaired absorption of the thick proteinoid material and clogging of the endolymphatic sac and duct.

Classification

We identify two forms of the disease, based on clinical severity and presentation: (1) insidious and (2) toxic (acute).

Insidious Form

This is a subclinical variety of the disease, resulting from passage of a minimal dose of bacterial toxins or inflammatory products across the round and oval windows. The oval window probably plays an insignificant role in this regard. Studies in animals have demonstrated that a large variety of substances including bacterial exotoxins (Schachern et al, 1981; Goycoolea et al, 1980) can pass from the middle ear to the inner ear via the round window membrane.

This insidious form of labyrinthitis may occur with chronic otitis media and may remain silent only to be discovered during postmortem examination of the temporal bone. A study of 75 human temporal bones with otitis media showed the presence of subtle cochlear changes in the form of serofibrinous exudates localized in the basal turn (Paparella et al, 1972). These serofibrinous exudates may be responsible for the gradual high-tone sensorineural hearing loss that may develop in patients with chronic otitis media (Paparella et al, 1970; Paparella et al, 1984). The hearing loss increases with the severity and duration of the disease (English et al, 1973).

In an experimental study in cats with various types of otitis media, it was demonstrated that the round window membrane becomes thickened and less permeable during chronic otitis media (Schachern et al, 1987b). Surgical grafting of the normal feline round window membrane results in an increase in the thickness of the membrane and a decrease in its permeability (Schachern et al, 1987b). We routinely scrutinize the round window niche and membrane during surgical procedures on the middle ear (tympanoplasties), particularly in patients with otitis media and sensorineural hearing loss. Chronic granulation tissue and cholesteatoma can invade the niche, and these are removed. When the round window membrane is thin or deficient, especially in children, we pack Gelfoam into the round window niche up to the sinus tympani in order to increase the membrane's thickness and thereby decrease its permeability.

Toxic (Acute) Form

Passage of a large dose of bacterial toxins to the inner ear results in a typical irritative labyrinthitis with a variable extent of labyrinthine failure. The patient complains of mild to moderate vertigo with nystagmus toward the affected ear. Mild to moderate concomitant sensorineural hearing loss is common. Temporary threshold shifts (TTSs) and permanent threshold shifts (PTSs) can occur as a complication of otitis media (Paparella, 1981; Paparella et al, 1984). This form of labyrinthitis occurs largely with acute otitis media, acute pyogenic meningitis, and early circumscribed osteitis of the bony labyrinth before the onset of endosteal thickening and during the serous (pre-purulent) stage of suppurative labyrinthitis. In an ongoing study, we have demonstrated for the first time the occurrence in experimental animals of a recoverable hearing loss, in the region of 2000 to 3000 Hz, produced by passage of non-viable bacterial (pneumococcal) particles from the subarachnoid space to the inner ear (Bassiouni et al, unpublished data). These preliminary data may explain the occurrence of TTS in some patients with pyogenic meningitis.

Treatment

Once the diagnosis of serous labyrinthitis is made, treatment should be instituted promptly and is focused on prevention of suppurative labyrinthitis by intensive antibiotic therapy and on treating the underlying causes (acute otitis media, meningitis, and labyrinthine fistula).

Autoimmune Labyrinthitis

The first notion of an autoimmune pathology of the inner ear was raised by Paparella and colleagues (1966, 1967) when they described for the first time the pathologic characteristics of a probable autoimmune inflammatory reaction of the inner ear, following experimental stapedectomy in cats. These investigators postulated that the inner ear was sensitized by the use of grafts of homologous fat at the oval window. They pointed out that the reaction was identical to that seen in the joints of subjects with rheumatoid arthritis and speculated on the possibility of similar autoimmune reactions in humans. This observation, found through serendipity, was then prospectively experimentally created in animals by the same group of investigators (Gromer et al, 1974). It is only in the past decade that aspects of the autoimmune phenomenon of the inner ear have been reinvestigated, and further immunologic and experimental evidence has been provided in support of this new pathologic entity (McCabe 1979; Yoo et al, 1982; Hughes et al, 1983; Harris, 1984; Arnold et al, 1985).

Clinical Picture

The possibility of immunologic injury is now being considered in a number of disorders of the inner ear that had been thought to be idiopathic. These include hearing loss associated with Cogan's syndrome, polyarteritis nodosa, and some cases of idiopathic progressive hearing loss. More recently, an autoimmune etiology has been suspected in patients with Ménière's disease and otosclerosis.

Generally speaking, autoimmune labyrinthitis is often a subacute condition that develops over a few weeks to a few months. Deafness is progressive or fluctuant, but is never sudden in onset. It is sometimes reversible either spontaneously or under the effects of steroids and other anti-inflammatory therapy. In more advanced conditions, however, the immunologic injury to the end-organs becomes permanent. The disease is often bilateral but may start unilaterally or may be asymmetric in clinical severity. Both auditory and vestibular functions may be affected in variable preponderances. Other manifestations of systemic autoimmune disease may be encountered elsewhere in the body. Treatment should be instituted early using steroids, cyclophosphamide, and other anti-inflammatory drugs.

Labyrinthitis Ossificans

Labyrinthitis ossificans is the healed end-stage of purulent labyrinthitis. By this stage, the labyrinth is usually sterile. Labyrinthine ossification can also be induced by trauma and by vascular insults of the inner ear. The term labyrinthitis ossificans, however, applies only to post-

labyrinthitic ossifications, which has an inflammatory origin.

Pathology

Healing of pronounced bacterial inflammation of the membranous labyrinth starts with fibroblastic proliferation, with deposition of many collagenous fibers in the perilymphatic space. Fibroblasts and loose fibrous connective tissue always precede the genesis of new bone. The osteoid matrix is formed by osteoblasts, which are derived from the endosteum, the modiolar spaces, and possibly from the undersurface of the basilar membrane (Sugiura and Paparella, 1967). The metabolic and biochemical alterations of labyrinthine environments provide the stimulus for induction of osteoblastic activity. Bone formation takes the form of irregular trabeculae or spicules of bone surrounded by dense collagenous fibrous tissue. In more advanced conditions, bone fills wide areas of the perilymphatic spaces, and haversian canals can be seen within the new bone. Labyrinthine ossification is often concentrated in the scala tympani adjacent to the round window membrane and opening of the cochlear aqueduct, and in the endosteal layer of the perilymphatic scalae near the modiolus. After the perilymphatic spaces have been replaced by fibro-osseous tissue, the endolymphatic spaces eventually become involved, and in advanced conditions the whole cochlea and wide areas of the vestibular labyrinth may be replaced by new lamellar bone.