Chapter 169: Surgery of Temporal Bone Air Cell System: Mastoid and Petrosa

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Indications for operation on the temporal bone air cell system can be divided into four categories: (1) acute inflammatory disease, (2) chronic inflammatory disease, (3) excision of temporal bone lesions, and (4) access to intracranial structures. The central figure in this scheme is the mastoidectomy. This chapter describes the basic concepts and application of the surgical anatomy of the air cell system in these various situations. In addition, the surgical concepts of mastoidectomy are elaborated in detail, and the variations necessary to achieve successs in the four categories are discussed. The disease processes that require this operation are presented elsewhere in this book, as are the associated procedures on the ossicular chain, tympanic membrane, vestibular system, facial nerve, and skull base.

Technique of Mastoidectomy

The most important otologic surgical procedure to be learned and mastered is a complete mastoidectomy. Whether it is used as the primary procedure or as part of a complex procedure, if it is performed improperly disease may be missed or left behind, or normal structures may be damaged. The anatomy must be learned from studying texts, dissecting in the temporal bone laboratory, observing in the operating room, and performing the procedure under supervision.

Most patients undergo the procedure in the supine position, with the head turned away from the surgeon. The choice of incision depends on the pathology and on the experience of the surgeon. Currently, most surgeons use a postauricular incision for chronic ear disease (Fig. 169-1, A). The postauricular incision was probably first described by Wilde in 1853 (Stevenson and Guthrie, 1949). It has always been used for subperiosteal abscesses. During the 1960s, it became fairly widely used for procedures for chronic ear disease. This increased use reflects the growing popularity of the intact canal wall or wall-up typmanomastoidectomy and the declining interest in the canal wall-down procedures.

It is important to remember that an infant (younger than 2 years old) probably has no mastoid tip to protect the facial nerve and that this incision must remain high. The incision can be carried down to the cortex and a layered subperiosteal flap created, which can be used to prevent postauricular depression or for partial obliteration (Palva, 1979). Exposure of the anterior middle ear, complete mastoid, and facial recess is excellent with the incision. It can also be converted to a canal wall-down procedure with minimal difficulty.

Before 1960, the endaural incision popularized by Lempert (1929) was widely used and is still useful at times. The endaural incision creates a large meatus and access to the temporalis fascia (Fig. 169-1, B). It gives more direct access to the posterior middle ear and allows opening of the poorly pneumatized mastoid without extensive cortex removal. In addition, it allows easy access to the external auditory meatus. Conversely, canal wall-up procedures are difficult and awakward to perform with this approach. The inclusion of tympanoplasty and middle ear procedures is relatively easy with either a postauricular or an endaural incision. The expansion of transtemporal bone approaches to the skull base and intracranially has led to several other incisions, usually further posteriorly and extending

superiorly onto the skull and down into the neck (Fisch et al, 1984).

Once the incision is made and the mastoid cortex is exposed (Fig. 169-1, C), the soft tissues are dissected to expose the surface anatomy of the mastoid (Fig. 169-2). The superior landmark is the temporal line, which extends from the root of the zygoma posteriorly above the external auditory canal to the occipital region. This surface landmark corresponds to the tegmen tympani, separating the middle fossa from the mastoid air cell system. The bony projection known as the spine of Henle lies at the posterosuperior rim of the external auditory meatus. Just posterior to this landmark is a series of perforations in the mastoid cortex known as the cribriform area. This is the surface landmark for the mastoid antrum. In the adult, the antrum is about 12 mm deep to the cribriform area. The area bounded by the temporal line and the spine of Henle and containing the cribriform area is known as Macewen's triangle. This is the area where most otologic surgeons initiate a mastoidectomy. Posteriorly is the opening for the mastoid emissary vein. Generally it is not necessary to dissect further than this point posteriorly. Inferiorly is the mastoid tip, which is partially covered by the insertion of the sternomastoid muscle. Sharp dissection of this muscle is necessary to separate these fibers from the bone. When the muscle is not dissected, the fibers tend to catch the drill and impede the dissection.

After the surface landmarks are clearly identified, the mastoidectomy is begun. The cortex, the dense layer of the external temporal bone, should be opened quickly with a large cutting burr. In the chronically diseased bone, this cortex is deceptively thick. In the "normal" bone, associated with surgery for tumor, the cortex is thin and the air cells are quickly entered. Patients with acute mastoiditis may have lost the cortex secondary to disease. Once the air cells are opened, the cortex should be removed completely. This step allows the greatest exposure as the dissection progresses medially. Generally, the line of dissection should be from posterior and inferior (Fig. 169-3). This approach allows the surgeon to pass under the bulge of the middle fossa and toward the mastoid antrum.

The plate of bone separating the middle fossa from the mastoid is called the tegmen tympani. This plate is usually easily identified and should remain intact. This landmark is important and should be sought out rather than avoided. The sigmoid sinus is identified. The air cells are dissected to expose the bony cover. The middle fossa dura and the sinodural angle (of Citelli) are defined. The petrosquamous (Körner's) septum is opened and the central mastoid air cell tract is identified. There are cells medial to the sigmoid sinus that should be opened and the posterior fossa dural plate recognized.

At this point, the mastoid antrum should be easily seen. The antrum is the keystone of the mastoidectomy. From it, the surgeon identifies the horizontal semicircular canal and the short process of the incus. These major landmarks must be recognized and preserved. Frequently the antrum contains inflammatory disease or cholesteatoma. Most often the air cells in the mastoid tip should be opened at this point. Although these cells are remote from the greatest areas of disease, the failure to open them may allow significant mucosal pockets to remain and erupt at a later time. This precaution may be more important in the canal wall-down procedure, in which the mucosa-lined air cells have nowhere to drain and may reactivate years later.

Dissection continues until the digastric ridge and the smooth bone of the medial wall of the mastoid tip are seen. It is necessary to thin the posterior side of the external auditory canal. Once this has been achieved, this bone is polished with a diamond drill to remove disease and to control bleeding. Dissection into the root of the zygoma may be useful to expose the epitympanic area. Unfortunately, this area is narrow and the middle fossa dura is vulnerable. A completed mastoidectomy should clearly expose landmarks rather than avoid them (Fig. 169-4).

Acute Inflammatory Disease

Before the introduction of sulfonamides and antibiotics, it was not unusual for acute or chronic otitis media to evolve into acute mastoiditis. Affected patients present with a history of acute otalgia, otorrhea, hearing loss, and occasionally vertigo or facial weakness. Clinically, they are acutely ill. The postauricular area is erythematous and edematous. Frequently, there is a postauricular swelling that pushes the auricle away from the skull. A classic finding is that the exteral canal skin is swollen and sagging in the postero-superior quadrant. Most often, the tympanic membrane is infected but intact. In addition, these patients are observed for papilledema, nystagmus, and facial weakness. The diagnosis is generally straightforward. Cultures and Gram's stain may be of some benefit in the immunocompromised patient, but they are not usually necessary to determine treatment.

Traditionally, radiographs of the mastoid were used to determine when coalescent mastoiditis was present. This diagnosis was based on the observation that the septa within the mastoid air cell system were dissolving. Currently, most otologists prefer CT of the mastoid because of its greater detail and accuracy.

Initial treatment is with appropriate antibiotics followed by surgery. Coalescent mastoiditis with a postauricular swelling is basically an abscess and must be treated as such with the traditional complete (simple) mastoidectomy. The procedure can be divided into two categories according to the age of the patient: > 2 years of age and ≤ 2 years. In the younger patients, the incision is fairly high t avoid the facial nerve. At birth the nerve comes straight out behind the external auditory canal. As the mastoid tip develops, it covers the facial nerve and pushes it downward.

CT can be used to determine the degree of aeration and the presence of a mastoid tip. The presence of a subperiosteal abscess indicates that the infection has eroded through the cribriform area in Macewen's triangle. When this abscess is opened, the mastoidectomy has largely been completed. The remainder of the mastoid cortex is removed, the mastoid cavity is irrigated, and the area is explored for evidence of cholesteatoma or other disease processes. As a result of the infection, this procedure may be fairly bloody and landmarks are obscured by granulation tissue. If the landmarks are not clear, it may be safer to drain the abscess, administer antibiotics, and reexplore later. Many surgeons leave a retroauricular drain in the mastoid for 24 to 48 hours. In addition, a myringotomy is indicated. The use of a ventilating tube is questionable because it is a foreign body in a site of infection. Intravenously administered antibiotics are useful for a short time postoperatively.

Chronic Inflammatory Disease

The most limited form of chronic inflammatory ear disease is the perforated tympanic membrane, which usually does not require any mastoid operation. The most prevalent form of disease is chronic otitis media with otorrhea but no cholesteatoma. Less common is chronic otitis media with cholesteatoma. The cholesteatoma may be either primarily or secondarily acquired.

Clinically, the usual presentation for these disorders is otorrhea with hearing loss. The otorrhea may be constant or intermittent. The hearing loss is generally conductive and may fluctuate as the disease changes. Otalgia, facial paresis, and vertigo are infrequent but ominous symptoms. On examination, there is often purulent discharge in the ear canal, which can be removed with suction. The canal skin and tympanic membrane are then examined. Most often, there is a perforation of the tympanic membrane, which may be central or marginal. In the past, a central perforation was considered safe, that is, operation might not be necessary. This generalization is not as widely accepted today. The presence of otorrhea or granulation is more important than the location of the perforation.

Another fairly frequent finding is the posterior retraction pocket. The tympanic membrane is actually intact but drops into the posterior middle ear and is pulled into the area known as the facial recess. This condition results in recurrent otorrhea and necrosis of the lenticular process of the incus. At times, posterior retraction pockets progress to a secondary acquired cholesteatoma; the distinction between posterior retraction pockets and secondary cholesteatoma is fuzzy at times. Another possibility is the attic retraction or primary acquired cholesteatoma. When the history and results of examination are considered together, the diagnosis is usually clear.

Initial theray may include antibiotic otic drops or systemic antibiotics. Definitive therapy is surgical. The preoperative evaluation usually includes audiometry. Cultures may be considered, but they are usually not necessary. The role of imaging studies is variable. They are not necessary in the straightforward case, but when there is any question about the extent of the disease or what procedure to use, these studies are useful.

Traditionally, plain mastoid radiography was the norm. It is of very limited value for major decisions. Tomography is useful but has been largely supplanted by CT, the current study of choice. CT allows excellent bone detail and can be manipulated to obtain excellent soft tissue images. Magnetic resonance imaging does not provide enough bone detail to be useful. However, as the technology evolves, it may become more appropriate.

Four basic procedures can be used to manage chronic otitis (with or without cholesteatoma): (1) tympanoplasty, which is reconstruction of the tympanic membrane and ossicular chain (see Chapter 168); (2) tympanomastoidectomy (canal wall up, intact canal wall, or combined approach); (3) modified radical mastoidectomy (nearly always with a tympanoplasty); and (4) radical mastoidectomy.

Tympanomastoidectomy

The goal of tympanomastoidectomy is to expose the disease, remove tissue as necessary, reconstruct the sound-conducting mechanism, and leave the anatomy as nearly intact as possible (Sheehy and Patterson, 1967). This procedure is particularly useful in patients with chronic otitis media and mastoiditis without cholesteatoma. It can be used in patients with cholesteatoma, but the significant risk of residual or recurrent disease (Cody, 1981; Smyth, 1976) necessitates careful follow-up for several years. The alternatives are to stage the procedure or to consider a canal wall-down procedure. Staging addresses residual disease but not the late recurrences that occur with posterior middle ear disease.

Currently, the postauricular approach is most widely used. An endaural approach can be used, particularly if the incision is extended above and then behind the auricle (Heermann incision). The mastoid or middle ear can be approached first (we use opposite approaches). The middle ear procedure is covered in Chapter 168. It may be necessary to remove portions of the scutum and lateral wall of the epitympanic space to expose and remove the disease. As a rule, the most difficult area is the posterior mesotympanum. This area contains the incus and stapes and the two recesses known as the facial recess and the sinus tympani (Fig. 169-5). Destruction of the lenticular process odf the incus is exceedingly common. Extension of the epithelium into the facial recess or the sinus tympani is considered one of the most common causes of failure of the intact canal-wall procedure. This problem may be handled by careful dissection, removal of the scutum, a Buckingham mirror, and staging of procedures. Opening the facial recess from the mastoid reduces the chance of residual cholesteatoma but increases the chance for recurrent disease (Fig. 169-6). An alternative is to take the posterior wall down and convert to a modified radical mastoidectomy.

The mastoidectomy portion of the procedure is performed as described earlier in this chapter. The dissection should be complete and all the structures clearly identified. This approach should reduce the amount of diseased mucosa in the mastoid and provide the exposure needed to examine the antrum and epitympanic area carefully. For patients in whom the disease extends into the posterior mesotympanum, the facial recess should be opened. This recess is bounded laterally by the bony anulus and medially by the descending portion of the facial nerve. Superiorly lies the short process of the incus, and inferiorly the recess is traversed by the chorda tympani nerve.

Generally, the dissection should be aimed directly at the facial nerve. The burr movement should parallel the course of the nerve, and the surgeon should realize that there is a bony covering. The nerve sheath has a characteristic white color, and usually a pair of capillaries is visibile in the sheath. A cutting burr used with a gentle touch is usually satisfactory and reduces the tendency to push and perhaps plunge into the facial recess.

This dissection is demanding and must be learned in the temporal bone laboratory. Many surgeons leave a small bridge of bone between the short process of the incus and the recess. The dissection can be extended inferiorly into the hypotympanum to remove disease; it is also useful for exposure of a glomus tympanicum tumor. One problem is the tendency to avoid the facial nerve by dissecting laterally and going through the posterior canal wall. This opening also creates a passage through which a posterior retraction can extend into the mastoid and result in recurrent cholesteatoma, which appears many years later.

Modified Radical Mastoidectomy

Bony (1910) first described modified radical mastoidectomy during the early part of the twentieth century. The procedure was performed for attic retraction cholesteatoma, and no thought was given to reconstruction of the drum head or ossicular chain. Preservation of hearing was possible in many patients, however, and this was an improvement over the traditional radical mastoidectomy. Currently, it is unusual for a surgeon to use the modified radical mastoidectomy without working on the middle ear. The major indications are a cholesteatoma that is though likely to recur or has recurred, or the presence of a horizontal semicircular canal fistula.

Some investigators believe that modified radical mastoidectomy is the ultimate in safe procedures (Smyth and Hassard, 1981); others believe that it is unnecessary and can be avoided by the use of secondary procedures performed 6 to 18 months after the initial procedure. This approach is known as staging. The major advantages of the modified radical mastoidectomy are (1) the ability to deal with the disease in one procedure, (2) the ability to see residual disease easily, (3) a lower incidence of recurrent disease, and (4) cost-effectiveness. The disadvantages are (1) altered anatomy, (2) the necessity to clean the bowl for the rest of the patient's life, (3) more frequent episodes of postoperative discharge, and (4) greater difficulty achieving hearing improvement. There are passionate, emotional, and often irrational arguments supporting both approaches. Suffice it to say that the modified radical mastoidectomy is a necessary part of any otologic surgeon's armamentarium.

Several incisions are available for this approach. The classic incision is the endaural incision popularized by Lempert (1929). This incision can be expanded in the Heermann incision by coming around the auricle. The endaural incision allows the surgeon to perform a subcortical mastoidectomy. The dissection begins at the scutum and opens the epitympanic space and then enters into the mastoid antrum. It then proceeds from medial to lateral, and the mastoid cortex can be left intact. This method works fairly well for the pure primary acquired cholesteatoma, but leaves many cells unopened in the tip and the sinodural area. Thus, this method is not generally considered adequate. With this approach, exposure to the posterior mesotympanum is superb, but many surgeons find that the ability to get the burr into position is hampered by the location of the auricle.

The postauricular approach is easily used for the modified radical mastoidectomy. Using the same incision as that for the tympanomastoidectomy, the mastoid cortex is exposed and the auricle is reflected anteriorly. A cortical mastoidectomy is then performed as described earlier in this chapter. For safety and better exposure, the facial recess is opened as with the intact canal-wall procedure. The posterior canal wall is now isolated and thin. It can be removed from medial to lateral or from lateral to medial, usually by removing the bulk of it with a rongeur and then smoothing the residual wall with a burr. Initially opening the facial recess keeps the facial nerve safe during removal of the posterior canal wall. It is mandatory to take down the air cells over the facial nerve to remove the ridge between the ear canal and the mastoid bowl. It is also extremely important to open all of the mastoid tip cells (Fig. 169-7).

After the mastoidectomy and middle ear work are completed, a meatoplasty must be performed. This procedure requires the removal of some of the chonchal cartilage at the

external auditory meatus. Experiences surgeons suggest that the opening should admit the thumb or forefinger. Temporalis fascia can be used to line the mastoid bowl. The mastoid bowl seems to heal more quickly. Also, thin silicone (Silastic) sheeting can be used to cover the mastoid bowl surface. This technique helps reduce adherence of the packing at the time of removal. Packing is placed in the mastoid bowl and left in position for 1 to 3 weeks. The packing is removed in the office, and otorrhea persists for a week or more. Once the bowl is epithelialized it must be cleaned at least annually. Many otologists do not allow patients to swim or get water in the ear. Others advocate wearing of ear plugs or using alcohol to dry the ear after water has entered.

Radical Mastoidectomy

Radical mastoidectomy is seldom used today, but is still an important component in the surgeon's bag of tools. On occasion, the disease is so extensive in the middle ear, particularly the sinus tympani area, that it must be totally exteriorized. Selection of this procedure must be made with the realization that it is a final procedure. Specifically, if performed properly, it will not be possible to reconstruct a tympanic membrane or create a middle ear space; therefore, the patient will have a maximal conductive hearing loss.

Conceptually, this procedure is an extension of the modified radical mastoidectomy: the incision, the mastoidectomy, opening of the facial recess, and taking down of the posterior canal wall are identical. The tympanic membrane, the incus, and the malleus are removed. The stapes superstructure is preserved if present. The inferior portion of the tympanic ring is lowered so that the external auditory canal and the floor of the hypotympanum are level and there is no ridge between them. All mucosa and diseased tissue are removed from the medial wall of the mesotympanum. The mastoid, the middle ear, and the external auditory canal now become one common cavity (Fig. 169-8). An attempt is made to seal the opening of the eustachian tube. Materials that have been used include septal cartilage, ossicles, bone chips, muscle, and fascia. A meatoplasty is necessary, and packing is placed in the bowl for 1 to 3 weeks. After the packing is removed, the bowl epithelializes and the aftercare is the same as that for the modified radical mastoid bowl.

If the cavity is dry, a standard hearing aid can be worn on this ear. If the cavity drains, then a bone conduction aid or the Audiant Bone Conductor can be used.

Obliteration Procedures

At times, part or all of a cavity can or should be obliterated. Sometimes the mastoid cavity created during a modified or radical mastoidectomy is large, making cleaning difficult and resulting in more frequent otorrhea. One mechanism to overcome these problems has been to obliterate much of the cavity with tissue. Generally, this has been local tissue rotated into position (Rambo, 1958). The most widely used tissue has been temporalis muscle or postauricular soft tissue (Palva, 1979). The ear will appear more normal and there will be less need to clean the cavity. It has also been used to reduce the incidence of otorrhea. Although the concept is attractive in theory, in fact, the soft tissue loses its bulk within a year and the cavity remains large. In addition, disease may be covered up, which may lead to major complications.

Complete obliteration of the mastoid and external auditory canal is used at times for chronic otitis media or as part of procedures related to cerebrospinal fluid fistula or a skull base operation (Harner and Laws, 1982). This procedure should be performed when there is no cholesteatoma, in the presence of a sensorineural hearing loss, and with good hearing in the contralateral ear. Another situation is the patient with chronic ear disease who is unable to cooperate with routine cleaning of a mastoid bowl. Again, local flaps of muscle or soft tissue can be rotated into position; however, a free graft of abdominal fat is commonly used and works well. The follow-up scans on these patients are interesting. The tissue nearly always resorbs and there is a relatively large air-containing space.

Petrous Apex Surgery

The advent of antibiotics radically changed the course of acute inflammatory disease within the temporal bone. Most acute middle ear infections are treated with antibiotics and then resolve. The mastoid air cells are involved, but only rarely do they require surgical therapy. The ultimate temporal bone involvement is in the petrous apex cells. The existence of these cells is much less frequent than in the mastoid system. This area around and medial to the otic capsule often remains as bone marrow and does not become pneumatized. When it does, five cell tracts can lead into the petrous apex: (1) peritubal, (2) perilabyrinthine, (3) posterosuperior, (4) posteromedial, and (5) subarcuate. A surgical procedure to make an opening into the petrous apex requires an understanding of these tracts and the more medial perilabyrinthine cells.

The diagnosis of petrous apicitis is based on clinical and radiographic findings. The patient usually has a history of protracted otaglia and otorrhea. If diplopia occurs in association with pain around the eye and otorrhea, then Gradenigo's syndrome is diagnosed.

Initial therapy is with antibiotics administered systemically and in appropriate doses. If pain and otorrhea persist, imaging studies should be performed to determine the extent of disease. If there is coalescent mastoiditis, the initial therapy may be a complete (simple) mastoidectomy and continued use of antibiotics. If pain and otorrhea still persist, then constructing an opening into the petrous apex is indicated. Three basic routes can be taken: posterior, anterior, or middle fossa (Eagleton, 1931; Lempert, 1937; Ramadier, 1933).

The posterior route begins with a complete mastoidectomy. It is important to expose the middle fossa and posterior fossa dura. Next, the perilabyrinthine cells must be opened to gain access to the petrous apex cells (Fig. 169-9). The perilabyrinthine cells lie anterior to the superior semicircular canal, through the semicircular canal (petromastoid canal) and the area posterior to the labyrinth, and anterior to the posterior fossa dural plate. The last-named area is used for the retrolabyrinthine approach to the internal auditory canal. Beneath the posterior semicircular canal and above the jugular bulb is another cell tract known as the infralabyrinthine tract. Air cell dissection is accomplished with curettes or a drill until the focus of infection is located. Experienced surgeons believe that the curette produces a better feel and is less risky.

If the posterior approach is unsuccessful in creating an opening into the abscess cavity, then the anterior approach is used. The posterior canal wall is removed and a radical mastoidectomy is performed. This procedure allows the hypotympanic and the peritubal cells

to be opened. If this maneuver is unsuccessful, then the internal carotid artery is followed to the apex according to the method described by Ramadier (1933) and Lempert (1937) (Fig. 169-10). After the radical mastoidectomy and opening of all the other cells are completed, the anterior canal wall is opened to expose the periosteum of the mandibular fossa. The tensor tympani muscle is removed from its semicanal, and the outer rim of the eustachian tube orifice is removed. This step exposes the bony covering of the internal carotid artery. The middle fossa dura and the geniculate ganglion afre exposed. The triangular area between these three structures is opened to pass into the petrous apex cells. This dissection is extremely demanding and requires that the surgeon study the original descriptions and spend time in the dissection laboratory before performing this procedure.

The third access is the middle fossa. Exposure is the same as in the middle fossa approach to the internal auditory canal. It is necessary to establish the location of the subarcuate eminence, the facial hiatus, foramen spinosum, and the superior petrosal ridge. Once these structures are clearly identified, the cells of the petrous apex can be opened from a superior approach, which is intracranial but extradural. This approach also creates a clear path into the mastoid air cell system and preserves hearing.