Mastoidectomy and posterior tympanotomy approach in cochlear implant surgery.

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Mastoidectomy.

Surgical technique in an adult patient in whom the air spaces of the middle ear have already been fully developed.

A simple mastoidectomy is done once the cortical exposure of the mastoid has been completed. Drilling at the level of the linea temporalis and slightly posterior to the external auditory canal will mark the beginning of this surgical step (Figure 7.169). The mastoidectomy needs not to be extremely wide or with the intent of removing most mastoid air cells. It has to be ample enough to be able to comfortably reach those areas and anatomical pointers related with the second surgical step which is the posterior tympanotomy. In this sense it is suggested to expose the body and short process of the incus in the fossa incudis, the bulge of the horizontal semicircular canal and the digastric ridge (Figure 7.170). Its size should be large enough to allow the passage of the cable that joins the electrodes and the receiver-stimulator.

It is necessary to open the lateral wall of the aditus and the posterior attic in order to adequately visualize the body and short process of the incus and the horizontal semicircular canal. It is important to avoid damage to the incus and to cause a sensorineural hearing damage by the transmission of vibrations from the drill to the cochlea. At this point it is suggested to switch from a cutting to a diamond bur, working at low speed and avoiding contact of the bur with the incus. These suggestions are within the concept of “atraumatic surgery” for the insertion of a cochlear implant (1).

In order to expose the digastric ridge it is suggested to extend the drilling inferiorly towards the mastoid tip. This implies the elimination -by drilling- of the intersinufacial cells. These surgical steps will allow a better drilling angle during the development of the posterior tympanotomy and the cochleostomy.

At the same time, during the performance of the posterior tympanotomy it is important to avoid an excessive thinning of the posterior wall of the external auditory canal. This can cause continuity solutions that will eventually end up with cholesteatomas because of invagination of the skin of the ear canal.

CONSIDERATIONS ABOUT MASTOIDECTOMY IN CHILDREN.

Pneumatization of the air spaces of the middle ear in children, varies during the development period. The middle ear and epitympanum end their pneumatization during the 33rd and 37th week of gestation, respectively. The mastoid process be comes pneumatized between the 34th gestational week and 10 to 14 years of age. Because of this reason the mastoid dimensions will have a variation of 1cm in depth from medial to lateral, 2 cm in its antero posterior width and 3 cm in its superior inferior length.

In a new born the mastoid will be basically represented by the antrum. When a mastoidectomy is done before and during the first year, after a brief drilling of the soft mastoid cortex, the antrum is promptly exposed. The scarce development of the tip will be represented by a non pneumatized spongy tissue that tends to bleed quite easily during drilling. This maneuver is essential in order to create sufficient space so that an adequate posterior tympanotomy can be done. Bleeding must be stopped with dry drilling with diamond burs or by applying bone wax.

POSTERIOR TYMPANOTOMY.

A posterior tymanotomy -opening of the facial recess of the posterior wall of the tympanic cavity- provides a direct access to the medial wall of the middle ear during mastoidectomy. This route facilitates an approximation in a straight line to the scala tympani in the basal turn of the cochlea. This is of great value at the time of insertion of electrodes in the cochlea (Figure 7.171).

When doing a posterior tympanotomy in a middle ear without malformations or pathology, one must take advantage of the anatomical pointers that lead towards an easier localization of the Fallopian canal. In this sense we suggest the reader to review the book of the author of this chapter (2).

Once the mastoidectomy is done and the anatomical pointers such as the short process of the incus, the horizontal semicircular canal and digastric ridge are identified, the main surgical maneuvers in doing a posterior tympanotomy are the following:

Thinning of the posterior wall of the external auditory canal from its lateral most aspect to a level determined by an imaginary line that traverses between the incus and the digastric ridge. This line represents the stretch through which traverses the third portion of the facial nerve. As the drilling approaches this area it is best to use a large or medium sized diamond bur, always maintaining a longitudinal drilling in relation to the facial nerve. The Fallopian canal can even be skeletonized in order to have a better idea of the nerve location. This will prevent facial nerve damage during cochleostomy and electrode insertion. On the other hand it is important to maintain the height of the external auditory canal and a thickness of the canal of two to three millimeters. This will prevent future complications related to the presence of a continuity solution in the posterior wall (Figure 7.172).

Once this point is reached, the drilling maneuvers will be done between the facial and the chorda tympani nerves. The bur will always be a diamond bur and the size should be such that it can pass in between both structures without harming them. Drilling will progress medially until opening the facial recess. The tympanotomy must be widened inferiorly in order to allow adequate exposure of the promontory area, especially of the round window niche, area in which the cochleostomy is to be done (Figure 7.173). If this widening is not done, one runs the risk of doing a cochleostomy in a superior position, with an opening in the scala vestibule and with a traumatic electrode insertion. At times the chorda tympani is sectioned, especially when it emerges superiorly from the third portion of the Fallopian canal. At the same time, the posterior tympanotomy in its highest portion, must allow visualization of the stapes and its tendon without the elimination of the buttress. In addition to providing anatomical references for the performance of the cochleostomy, the visual control of the stapes can be useful if the stapedius muscle contraction is to be evaluated by stimulation with the electrodes. This evaluation provides useful information in order to establish C thresholds in cochlear implant programming.

Once the mastoidectomy and posterior tympanotomy are completed, a straight approximation to the scala tympani and the basal turn of the cochlea is available and a cochleostomy can be done. In other words, with these surgical steps “a hole, in a hole, in a hole” has been developed (Figure 7.174).

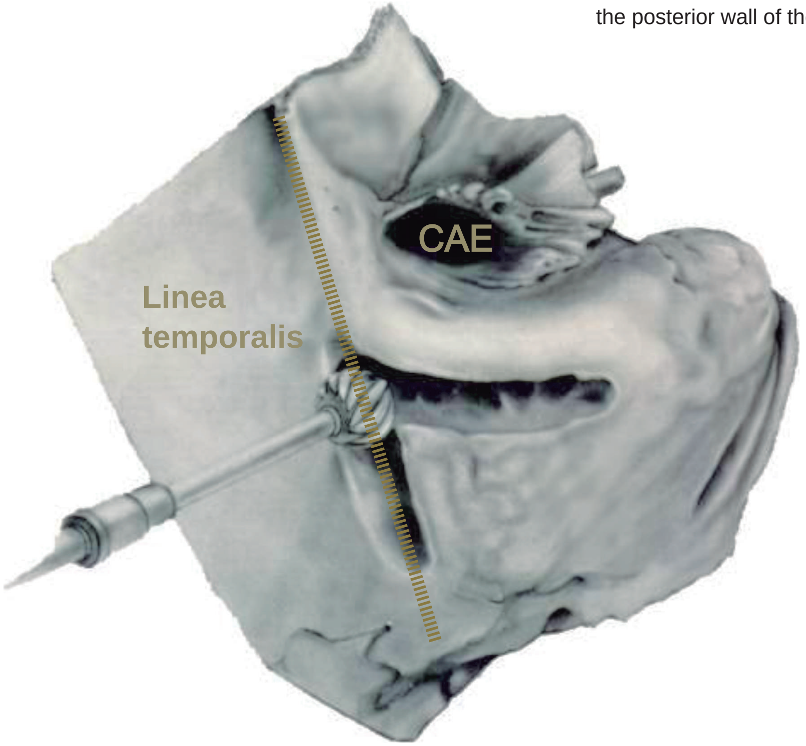
POSTERIOR TYMPANOTOMY IN CHILDREN.

As a consequence of an incomplete development, In the case of children the third portion of the facial nerve is localized more superficially than in adults. It is important to be aware of this anatomical fact in order to avoid damaging the facial nerve during mastoidectomy and posterior tympanotomy. It is important to consider that the second genu of the facial nerve has a wider angle (more open) in children than in adults. The angle of this second genu is always over 90 degrees, varying according to Beauvillain (3) between 92° and 125°. This author describes the width of the Fallopian canal at the level of this genu as identical in children and adults, however, this is not true for its length. In the new born and in children, the genu projects and curls posteriorly.

It is suggested that these surgical steps are conducted with facial nerve monitorization, especially in those cases in which the CAT scan suggests a malformation of the temporal bone or in the craniofacial region.

As it has been already described, doing a posterior tympanotomy requires thinning of the posterior wall of the external auditory canal. This is especially important in the case of children since they have an immature Eustachian tube, and thus it is more frequent for them to have negative pressures in the middle ear spaces for longer periods of time. This will facilitate the occurrence of skin retractions into the external auditory canal in case of bony dehiscences of the posterior wall, favoring the development of cholesteatomas.

Fig. 7.169. Starting the mastoidectomy. The outlines of the drilling of the mastoid cortex are shown. These are at the level of the temporal line (linea temporalis) and the posterior wall of the external auditory canal.



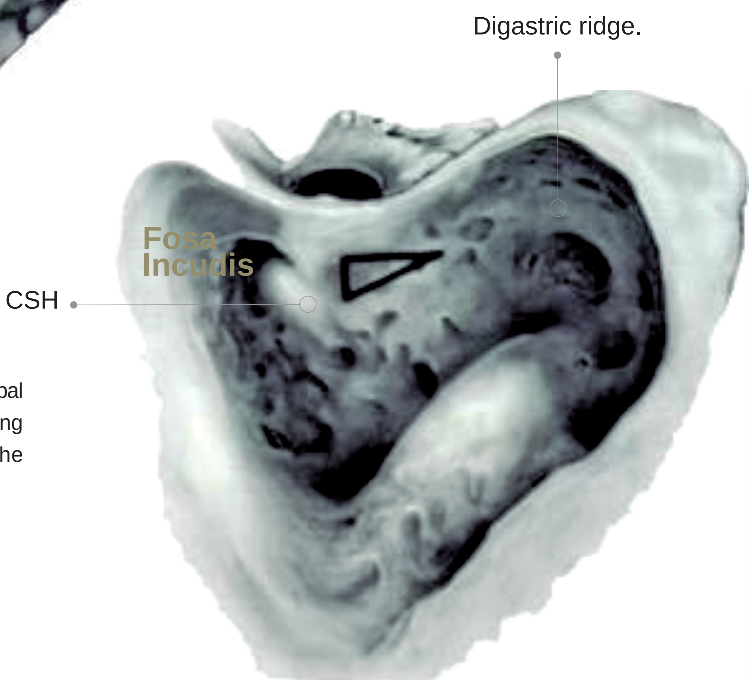


Fig. 7.170. Localization of the three principal anatomical pointers to be identified during mastoidectomy in order to facilitate the posterior tympanotomy procedure.

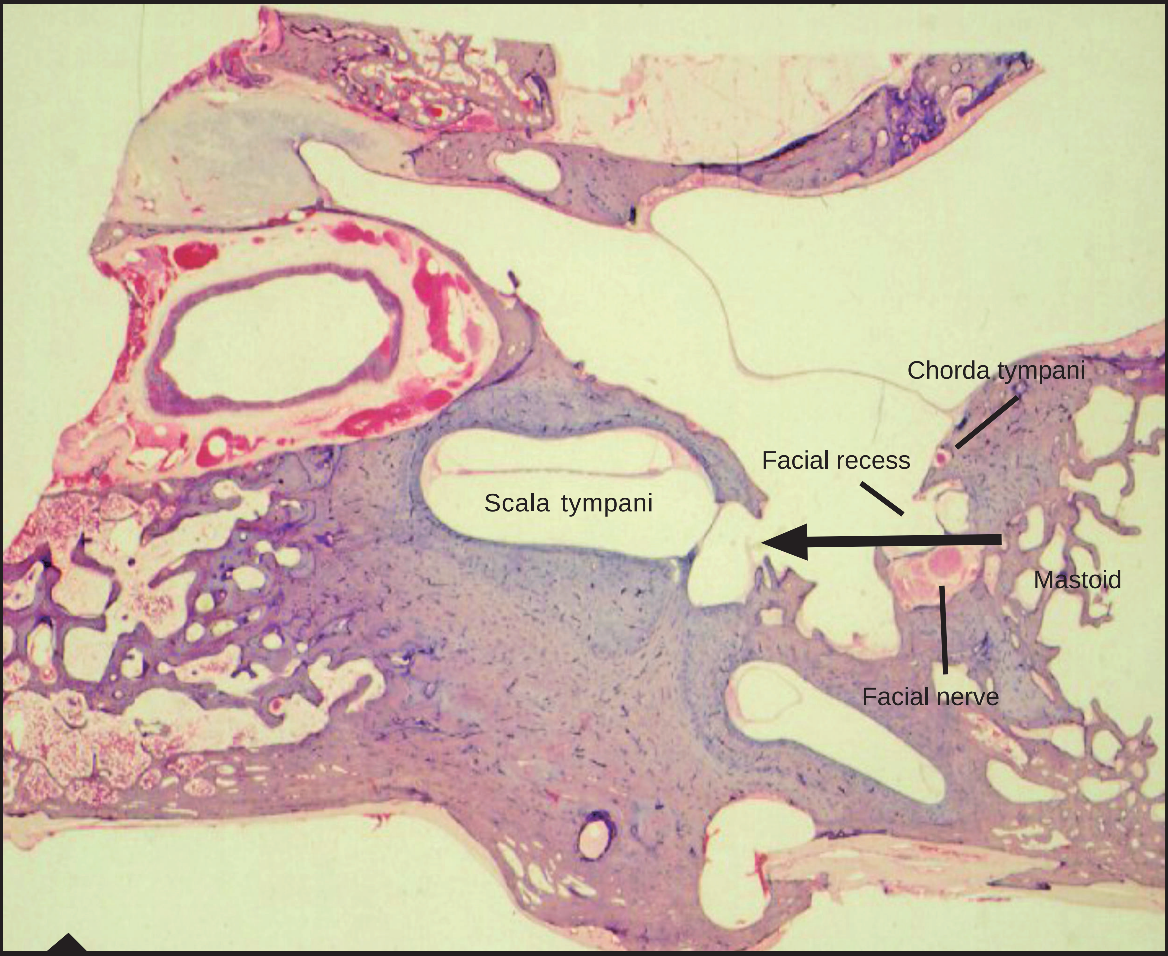


Fig.7.171. Histological preparation of a temporal bone which shows the straight approximation to the scala tympani of the cochlea that is obtained after a mastoidectomy and a posterior tympanotomy.

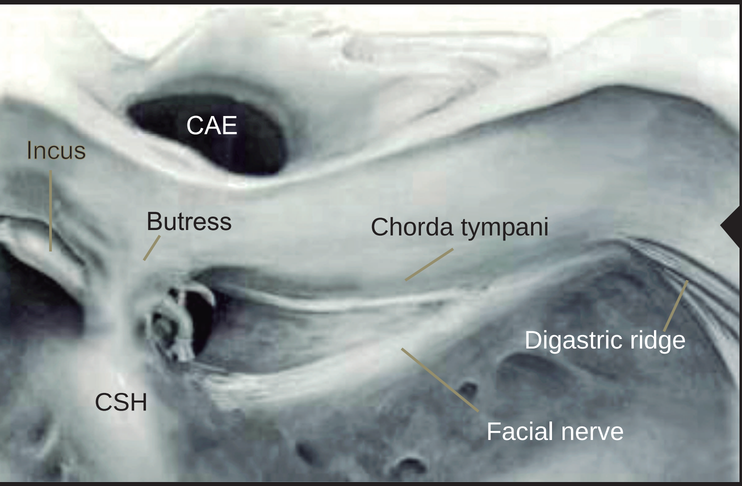


Fig.7.172. Graphic representation of the anatomical structures that are exposed with a posterior tympanotomy.

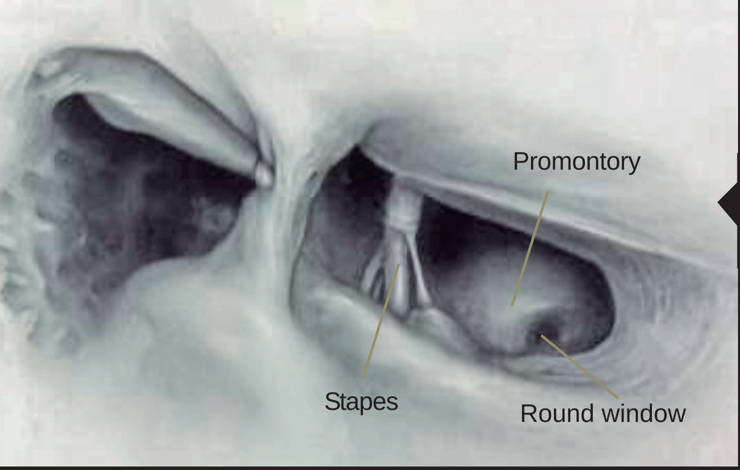


Fig.7.173. Graphic representation of the anatomical elements that are visible through the opening of the facial recess after a posterior tympanotomy.

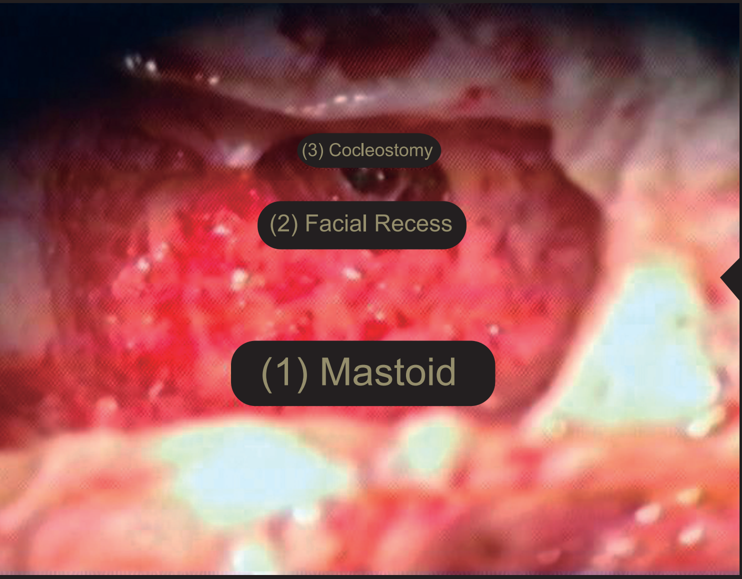


Fig.7.174. “A hole. In a hole, in a hole.” A sequence of mastoidectomy, posterior tympanotomy and cochleostomy, which provide a direct linear approach to the cochlea in cochlear implant surgery.

References.

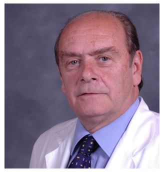
1. LEHNHARDT E. Intracochleäre plazierung der cochlear-implant elektroden in soft surgery technique. HNO 1993; 41: 356-359.

2. MANRIQUE M. Guía para la disección del hueso temporal. Ed. biblio stm, Masson S.A. Barcelona, 1998.

3. BEAUVILLAIN C, SIMON C, LEGENT F. Contribution à l'étude de l'anatomie du nerf facial du nouveau-né 2ª et 3ª portions: aplication chirurgicale. Ann Otolaryngol, 1982; 99:223-230.

Active electrodes by the antrum.

Santiago Arauz, Marcos Goycoolea.



Mastoidotomy/Tympanotomy Approach

ADVANTAGES

1. Technical simplicity.

2. Involves less bone drilling and tissue removal.

3. Carries almost no risk to the facial nerve.

4. Allows for direct view of and work in the round window niches.

5. Provides a better angle in the basal turn of the cochlea for sliding the electrode, making full insertion easier.

6. Small postauricular flap carries less risk of hematoma or infection; requires no drains; makes healing easier.

7. Allows faster recovery and shorter hospitalization.

SURGICAL STEPS

1. Endaural incisions (Lempert I and II) or small postauricular incision.

2. Canal incisions at 6 and 2 o'clock.

3. Exposure of the middle ear.

4. Drilling of the round window niche and visualization of the round window membrane.

5. Small atticotomy.

6. Mastoidotomy.

7. Postauricular incision.

8. Removal of temporal muscle and periosteum.

9. Drilling of a seat for the internal receiver.

10. Introduction of the electrode into the antrum and middle ear.

11. Insertion of the electrode into the cochlea.

12. Securing of the internal receiver.

13. Closure, packing, and a mastoid dressing.

PROCEDURE

The procedure is usually done using a small post auricular incision, however, for didactic purposes -and due to the fact that the postauricular incision for cochlear implantation is described in this same chapter- endaural incisions will be described.

The first incision (Lempert I) is made semicircumferentially between 6 and 12 o'clock on the posterior wall at the bony cartilaginous junction. The second incision (Lempert II) runs between the tragus and helix (at the incisura). The extension of this incision is approximately 0.75 cm. The posterior canal skin (cartilaginous portion) is preserved and gently elevated with a small periosteal elevator, clearly exposing the entire posterior bony canal (Fig. 7.175A). Two-prong retractors are used for exposure; occasionally three-prong retractors are needed.

With a scalpel, vertical incisions are made at 6 and 2 o'clock. In a completely dry field, a flap is elevated and the middle ear cavity is entered beneath the annulus. All anatomic structures and landmarks are visualized. Using stapes curets, the posterior canal wall is enlarged and a small atticotomy is done (Fig. 7.175B). Special attention is paid to the round window niche. The anterosuperior portion is removed with a

small bur and the round window membrane is brought directly into view (Fig. 7.175C). Any additional drilling needed for exposure is delayed until the electrode is inserted (see Posterior Tympanotomy [Facial Recess] Approach).

A piece of Gelfoam is used to cover the round window and a large piece of cotton is placed over the ear canal. This avoids contamination by bone dust and debris from the mastoidotomy drilling.

A mastoidotomy is done by drilling in the fossa mastoidea toward the antrum (Fig. 7.175D). The opening should be large enough to visualize the antrum. The posterior edge is beveled and all sharp bony edges are smoothed. The incus is disarticulated from its stapes and malleus attachments with a joint knife and totally removed. If desired, a dummy electrode can be inserted through the mastoidotomy opening and into the niche to verify the adequacy of the exposure. The middle ear and mastoid are then filled with an antibiotic solution.

A postauricular incision is needed for the sole purpose of placing the internal receiver; it should be made at or above the linea temporalis, allowing enough space without interfering with the use of eyeglasses. Lidocaine (Xylocaine) 2% with 1:100,000 epinephrine is injected. The circumferential incision measures 3 to 3.5 cm and is deepened through the subcutaneous tissues until the temporal muscle is reached (Fig. 7.175E, F). The seat size for the internal receiver is measured, and the corresponding underlying temporal muscle and periosteum are removed. The periosteum is saved for grafting the round window niche. The bone seat is drilled down to accommodate the receiver (Fig. 7.176A) and, depending upon the type of receiver, additional holes are drilled either for sutures or for screw placement (see Posterior Tympanotomy [Facial Recess] Approach).

An electrode guide is passed from the endaural to the postauricular incision by tunneling it beneath the temporal muscle. An electrode guide, which is similar to an antrum trocar, is specially curved and has a blunt distal opening to avoid damaging the electrode (Fig. 7.176B). The obturator is removed and the electrode introduced into the guide; the guide is then withdrawn and, with it, the electrode is carried into the mastoidotomy opening. It is then passed to the antrum and into the middle ear. The exposed round window membrane is detached with an angled pick, and the electrode is introduced with a nonserrated baby alligator forceps in an angle pointing toward the basal turn of the cochlea, immediately past the hook (Fig. 7.176D). The opening of the round window is sealed with temporalis fascia or periosteum wrapped around the electrode (Fig. 7.177A). Small pieces of Gelfoam are then placed lateral to the periosteum graft.

With a postauricular approach the electrode array is introduced directly into the antrum and into the middle ear, without the need of an electrode guide.

The internal receiver is then secured in place with sutures, the ground electrode is placed under the temporal muscle, and the rest of the fascia or periosteum is used to seal the antrum.

The canal flap is repositioned. Gelfoam and an antibiotic ointment are used in the distal two thirds of the ear canal, and gauze is embedded in antibiotic ointment in the distal one third. Incisions are closed with subcutaneous 3-0 chromic catgut or 3-0 Vycril rapid and skin sutures of 4-0 silk or nylon, and a mastoid dressing is applied.

Figure 7.175.

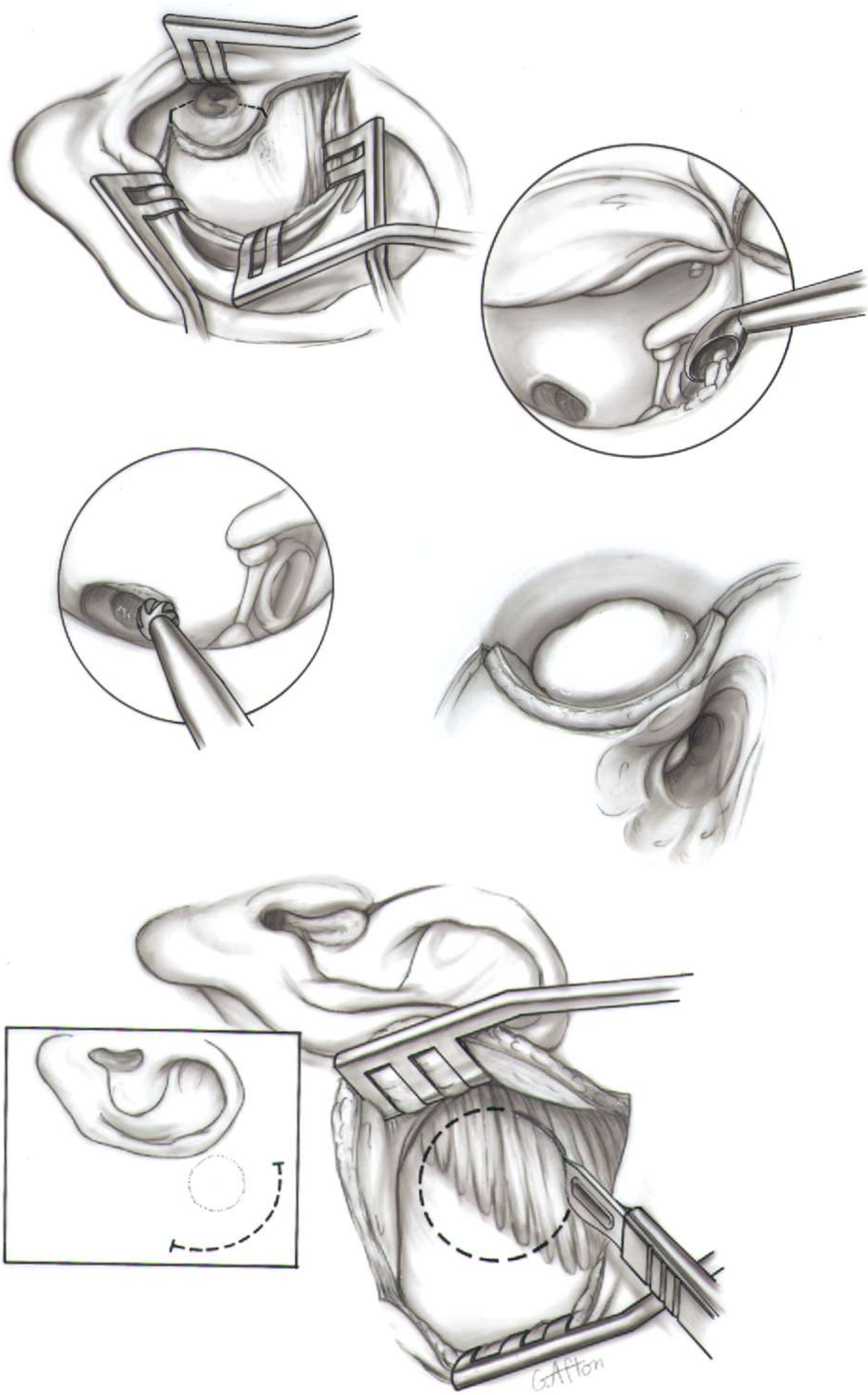
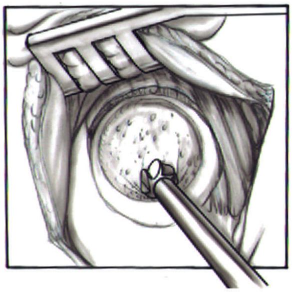
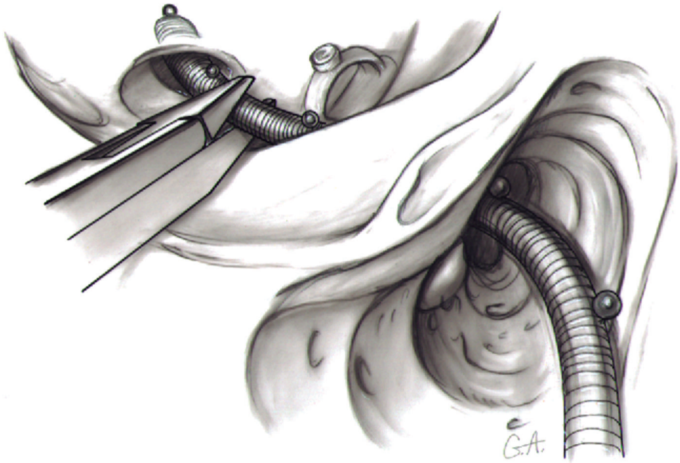
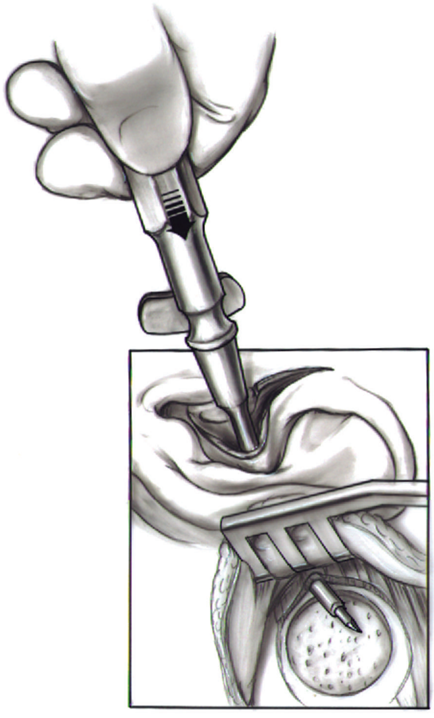


Figure 7.176A, B,D.







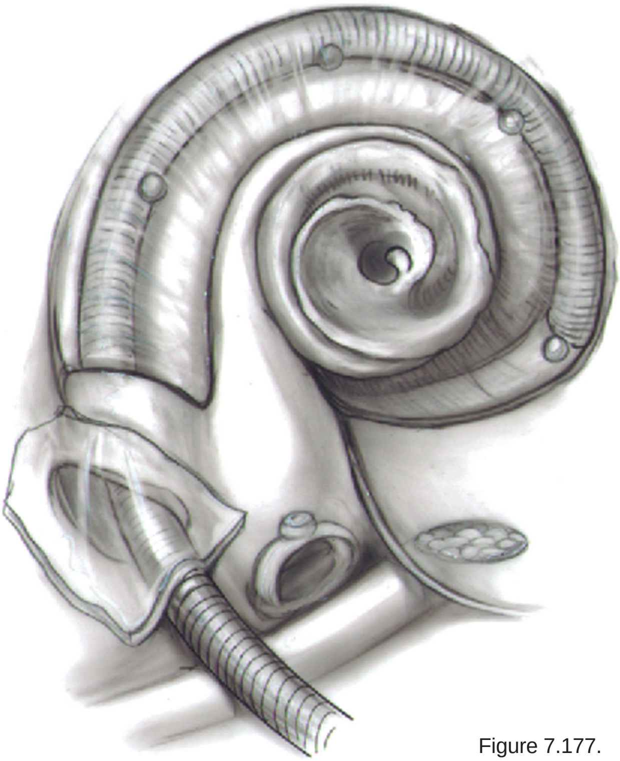


Figure 7.177.

The endomeatal approach.

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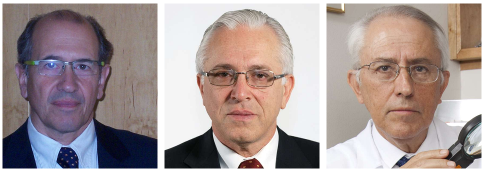

Purpose.

The usual technique for cochlear implantation (CI) involves an antromastoidectomy and a posterior tympanotomy (PT) through the facial recess (1). The endomeatal approach (EMA) is a surgical technique that uses a direct approach through two natural pathways: the external auditory canal (EAC) and the round window (RW) (18, 19).

Our purpose is to describe the advantages of this approach; not only in conventional cochlear implant surgery, but in all those cases in which the posterior tympanotomy approach is difficult to perform.

Highligts.

OPTIMAL INSERTION PLANE.

The scala tympani (ST) starts its basal turn immediately alter the round window (RW), describing from its onset a spiral curve centered in the modiolus. Therefore, in its way to the cochlear apex the ST longitudinal axis is changing its direction continuously, going initially downward and forward, after a few milimiters takes a horizontal, to the front and inward direction, and after that an inward and upward direction. The RW and its membrane are like an oblique base for the ST cylinder, with its visible face looking outward and backward.

The safest site for positioning of the electrode array is the floor of the scala tympani (21). The projection of the axis of the basal spira passes between the posterior border of the oval window and the pyramidal process, and inferiorly by the internal aspect of the crista fenestra. Therefore, in order to avoid damage to the neurosensory structures, the direction of an optimal imaginary insertion plane must be from postero-superior to antero-inferior (Figs. 7.178, 7.179, 7.180).

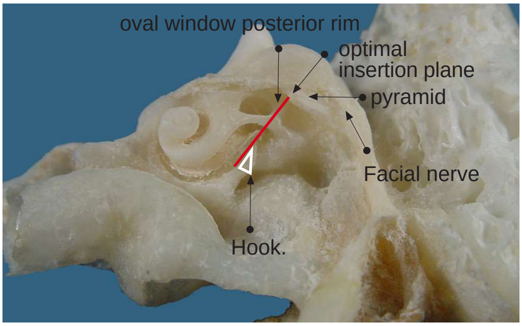

Fig.7.178. Optimal insertion plane (red line). Dissected left temporal bone, courtesy of Rodrigo Posada, MD.

Depending on anatomical variability, this projection can coincide with the posterior wall of the external auditory canal or pass in front of it. This is an anatomical fact to have in mind during surgery in order to achieve good positioning of the electrode array.

THE GROOVE

EMA requires making a bony EAC groove for electrode lead (EL) lodging, in order to avoid contact between the skin and the EL that could lead to its extrusion (Figure 7.179).

A safe anatomic area to perform the groove with no risk for adjacent structures like facial nerve, chorda tympani, eardrum and ossicular chain were studied and finally established with these landmarks: the incus and pyramidal process in the inner EAC side, and the outer border of tympano-squamous suture in the outer side. This -groove placement is also on line with the axis of the more basal segment of ST, so the EL does not suffer any degree of bending after it is finally positioned in the ST.

From the pyramidal process in up, there is enough room to drill a groove with a 0.5 mm cutting burr. An overhang is left in the superior groove's edge, in order to retain the electrode lead and avoid its contact with the EAC skin, therefore preventing extrusion (Figs. 7.179, 7.180).I mm wide and 2 mm depth is enough to cross the fallopian canal at a safe distance and lodge the EL. It is convenient to leave an overhang that retains the EL (Fig. 7.180).

The pyramid level is the best place for the following reasons:

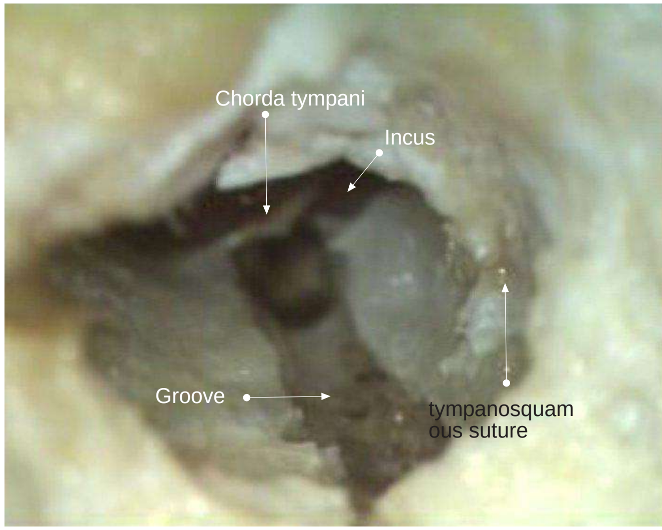

Fig.7.179 Left temporal bone dissection with the groove landmarks.

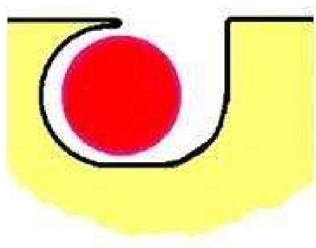

Fig. 7.180. Schematic groove´s cut, showing the overhang that retains EL.

- a safe distance to FN even in infants;
- good direct control of fallopian canal, visible at oval window;

- good position for electrode insertion in the plane described before;

- EL does not cross over the incus process in its way to the RW.

Surgical technique.

FIRST STAGE: ENDOMEATAL

a. Anterior tympanotomy and exposure of the RW membrane

This stage is aided with an autostatic ear speculum. It starts with an endomeatal stapedectomy-like but a few millimeters more external-skin incision, in the posterior wall of the bony EAC. The skin is carefully elevated and the tympanic annulus is desinserted. The tympanomeatal flap is driven forward over the anterior eardrum quadrants, respecting the malleolar eardrum insertion. At this moment the RW and promontory are visualized. The tympanic bone margin must be lowered with a curette or diamond burr in order to complete the RW visualization-if necessary and to expose the chorda tympani, the pyramidal process, the incus long process, the stapes, the oval window and the fallopian canal (Fig. 7.181).

With a Skeeter microdrilt the overhang bone projection that protects the RW is totally removed until complete RW membrane exposition. The membrane is preserved at this stage in order to prevent perilymph lost and bone dust entrance into ST

b. Endomeatal groove.

Taking as reference the location of the RW, the pyramidal process, and the incus in the inner border of the EAC, and the tympano-squamous suture in the outer border, a 1 mm width and 2 mm depth groove is performed in the EAC posterior wall from inside to outside, in the EAC axis direction, with a Skeeter microdrill (Fig. 7.179). As stated earlier, an overhang is left in order to retain EL. In order to avoid CT damage, in some cases it is necessary to separate it from the tympanic ring. The bone dust is carefully cleansed with suction-irrigation. The TC and the tympanomeatal flap are protected with gelfoam.

SECOND STAGE: RETROAURICULAR

Groove lateral segment. Receiver-stimulator well and second well for the remaining EL

A retroauricular skin incision with a small postero-superior extension is performed [4] and the muscle-aponeurotic plane is dissected one centimeter in both incision lips. The muscle is incised to the bone and the periosteum is detached creating in a posterior manner a pocket for the receiver-stimulator, and discovering in an anterior manner the mastoid bony surface up to the EAC. The dissection is continued into the EAC until the endomeatal skin incision external lip is detached from the bone, and the internal part of the bony EAC is visible, with the groove carved in the first stage. A classic mastoid retractor can be used or one with a valve that protects the skin of the posterior wall (Fig. 7.183). Then the groove drilling is resumed and pro-longed up to the external mastoid surface (Fig. 7.182). The receiver-stimulator (RS) well is drilled and a 2 cm diameter and 3 mm depth flat second well is performed in front of the first one. This second well is connected forward to

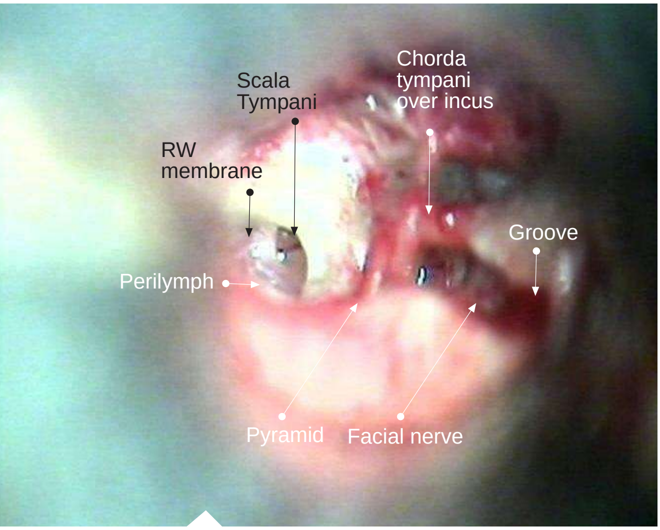

Fig. 7.181. EMA RW cochleostomy. Anatomical relations.

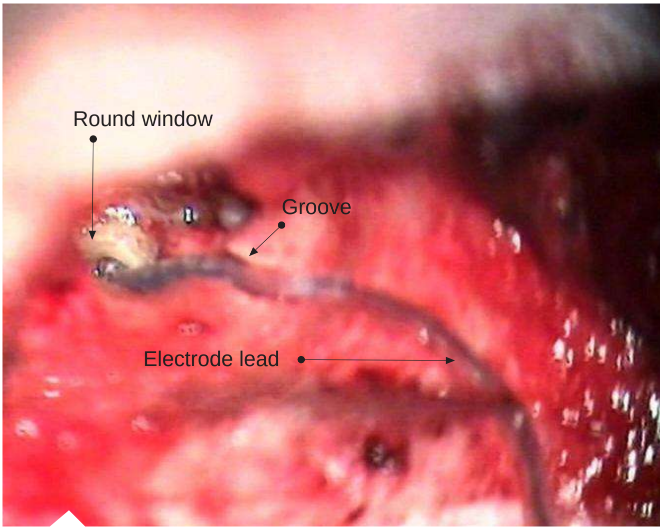

Fig. 7.182. The EL inside the groove. Deep insertion through the RW. EMA second stage.

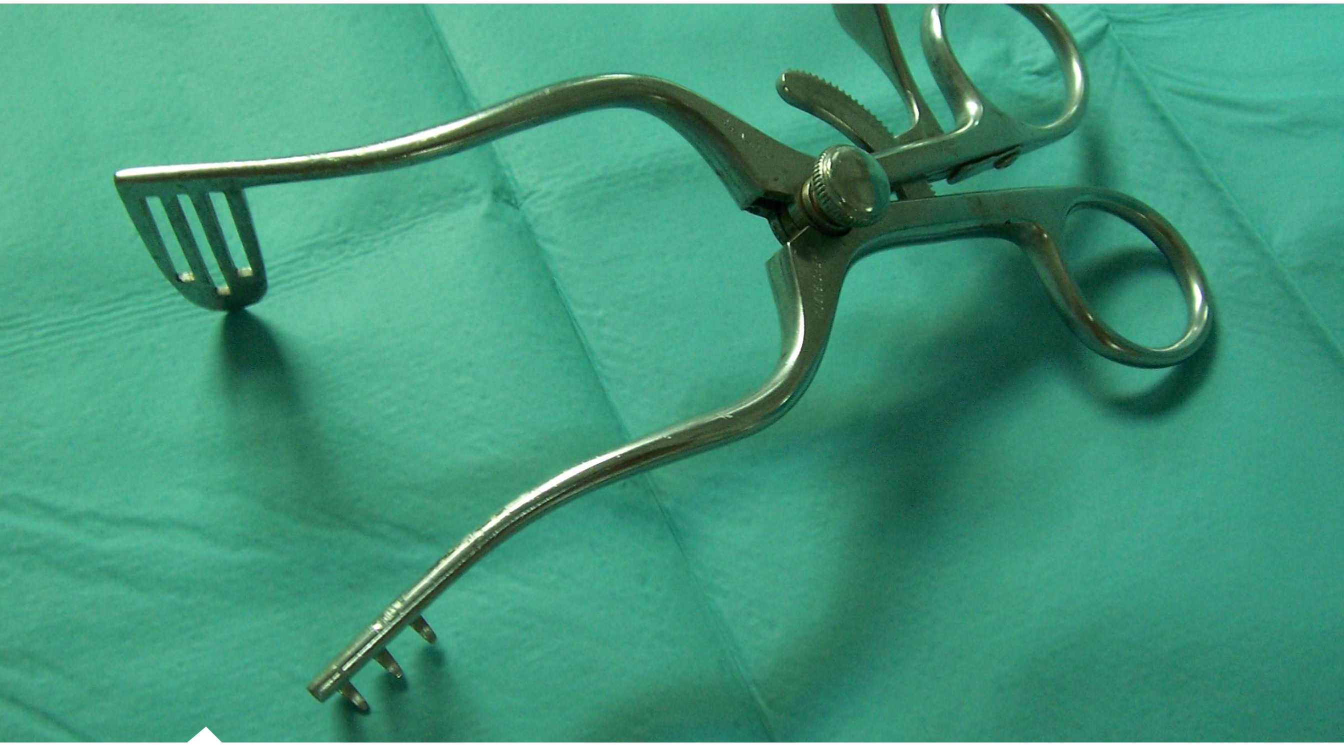

Fig. 7.183. Mastoid retractor with a valve. EMA with retroauricular incision.

Fig. 7.184. Groove. Cochlear implant in postirion. Left ear.

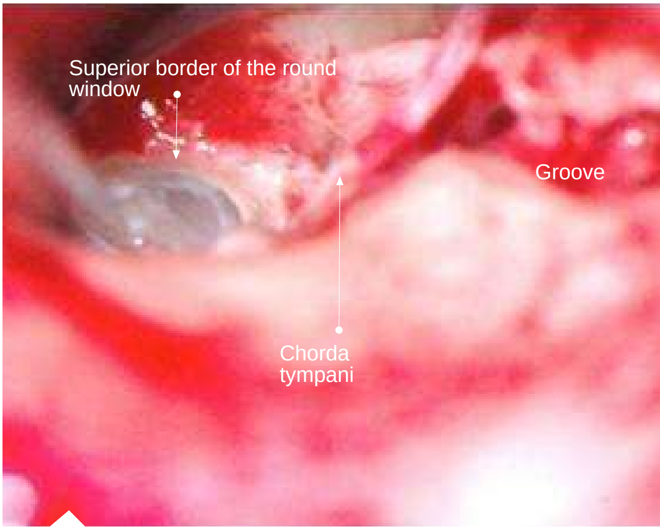

Fig. 7.185. Secondary tympanotomy from the superior border of the round window membrane. Left ear.

the groove and backward to the RS well. The TC Gelfoam protection is removed, and the RW membrane is incised with a pick from its superior edge to the antero-inferior edge, taking care with its posterior aspect that is in close relation with the spiral lamina (Fig. 7.181). The RS is placed in the pocket and the proximal portion of the electrode array is introduced through the EAC up to the TC.

The tympanotomy is wide open, with the tympanomeatal flap driven forward and protected with Gelfoam. It results in a clear RW exposure, since the posterior EAC skin and the eardrum do not bother any surgical maneuver.

Optimal plane of electrode insertion.

It is necessary to consider that the EMA allows the EA to come from a more superior and anterior position, .without being limited by the posterior wall as it happens in the PT approach.

The insertion is made in an up to down, back to front direction, from the EAC postero-superior part up to the superior edge of the round window. That results in an insertion angle approximately 30° more anterior, and also 15° more superior compared with the PT insertion angle. That explains why EMA avoids to crush modiolar wall, spiral lamina and/or basilar membrane as Roland et al. [3] refer, coming from a more vertical position and with enough space in the EAC to lead the EA to slide over the ST curved outer wall, in a more inferior posi-tion, farther-from the basilar membrane and spiral lamina and running away from the inner wall.

Once the insertion is done, the EL is gently introduced inside the groove (Fig. 7.182) and kept in place carefully filling the groove with bone pate [5] (Fig. 7.186).

The RS is sutured in its bony well to the surrounding periosteum. The remaining EL is located inside the flat second well that has been performed with undercut edges to prevent extrusion. The ground electrode is located under the periosteum, in contact with the temporal bone, and the retroauricular incision is sutured by planes.

THIRD STAGE: ENDOMEATAL

RW seal. telemetry measurements. Tympanomeatal flap restoring.

The RW is sealed with connective tissue (Fig. 7.186). The telemetry and electric stapedial reflex measures are carried out, the tympanomeatal flap is restored and the skin adapted over the groove. The final stage ends by carefully dressing with Gelfoam the EAC internal segment and with gauze in its external part. The retroauricular incision is dressed as usual.

Fig.7.186. The electrode does not contact the ossicular chain. Round window seal and groove obturated.

Ema with endopreaural (lempert) incision.

It is indicated in eras with a previous mastoidectomy in which it is not convenient to have the cochlear implant in a position that is related to the previous procedure (eg. meningocele, fistula, radical surgery, etc.) Figs. 7.187, 7.188.

EMA allows us to be less concerned with the status of the mastoid, especially in cases of radical cavities. EMA is an alternative surgery that allows avoiding the mastoid and respect the results of the previous surgery. Depending on the surgeon´s surgical habits It can also be simpler to perform in ears without previous procedures.

A. INCISION.

A superior and posterior extended endopreaural incision is done (Heermann incision). The extension will depend on the implant that is being used and it should be done in one plain.

B. GROOVE.

The endomeatal groove is extended by drilling the superior wall of the EAC until reaching the external surface of the temporal squama. It is a safe anatomical area and the dimensions of the groove are similar to those that are done in the mastoid (1mm wide by 2 mm deep). It is not necessary to do any extra drilling for the excess cable because thae distance that the electroide guide has to travel is longer due to the abscense of a mastoidectomy, The electrode guide is placed subperiostically as if it were a reference electrode.

C. ROUND WINDOW.

EMA with a Lempert (endopreaural) incisión allows theuse o fan autostatic speculum at the moment of insertion of the electrodes and this facilitates control in the round window.

D. INSERTION.

The electrode array should be placed first, and then the referente electrode. Otherwise the electrode array can end up being short during the insertion maneuvers. The reference electrode is placed under the inferior lip of the incision and is introduced until the exit of the electrode guide is approximately at the level of the EAC so that the receiver ends up completely covered by the musculo-cutaneous plane but without placing it in its bony bed. The electrode array is then inserted through the autostatic speculum, and once it is done the speculum is withdrawn. Once this is done, the reference electrode (RE) is placed in its definite position.

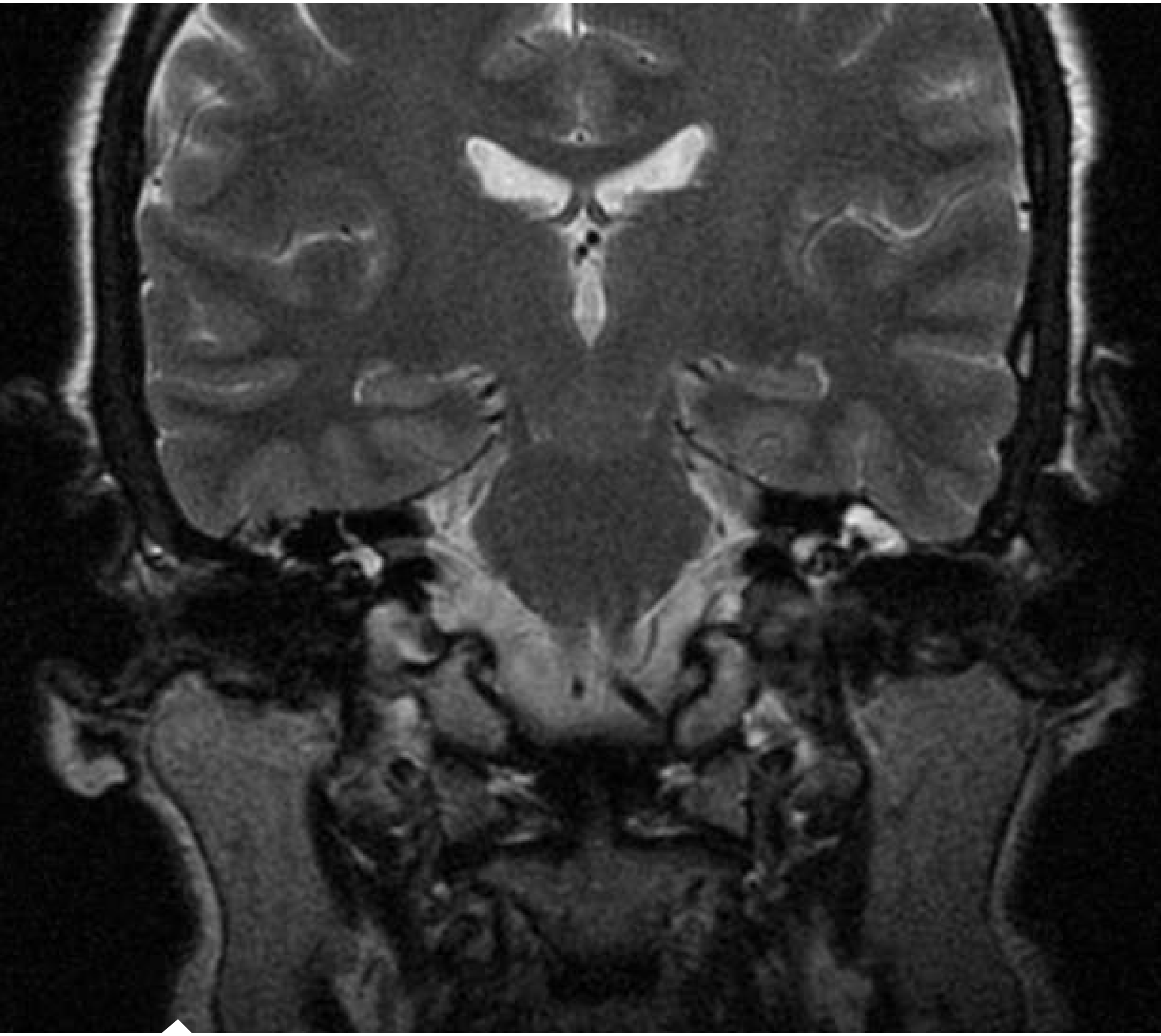

Fig. 7.187. Left ear with a previous mastoidectomy with labyrinthectomy. EMA with Lempert incisión avoids mastoid compromiso and risk to the facial nerve.

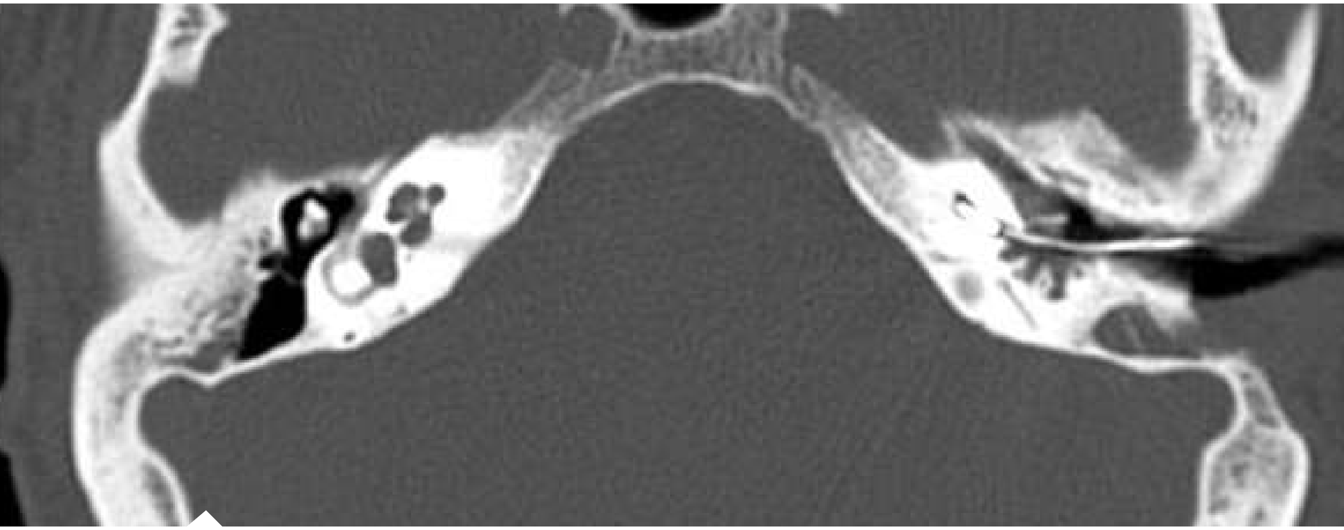

Fig. 7.188. Control CAT scan. EMA with endopreaural incisión (Lempert) with previous mastoidectomy in the left ear.

Fig 7.189. EMA with endopreaural (Lempert) incision.

E. POSITIONING OF THE RE.

The RE will have a more horizontal position compared to the retroauricular approach because the electrode guide must be directed to the superior wall of the EAC and not to the facial recess. Fig 7.189.

F. FIXATION.

Fibrin glue can be used in the middle ear and the groove and at the level of the RE. It helps to fix the implant in tese cases and avoids unwanted displacements during the surgical maneuvers at the same time that it provides isolation. The surgical stages are similar to thos of EMA with retroauricular incision.

MODIFIED EMA TECHNIQUE FOR PEDIATRIC SURGERY.

In children the mastoid fossa (anterior well) is replaced by a deeper mastoid cavity that requires thinning of the posterior wall of the EAC in its external 2/3rds but without opening the mastoid antrum (17).

The external portion of the groove is communicated with the mastoid cavity, transforming the groove in a narrow open cleft that will allow the passage of the electrode array into the bottom of the cavity. The groove is limited to the internal third of the osseous EAC, thus avoiding tension and displacement during the development of the osseous canal. Fig 9. The cleft and short groove are obturated with bone paté. The excess cable adopts a position that is similar to the transmastoid approach but limiting the drilling of healthy tissues without exposing the mastoid antrum. Fig. 7.191.

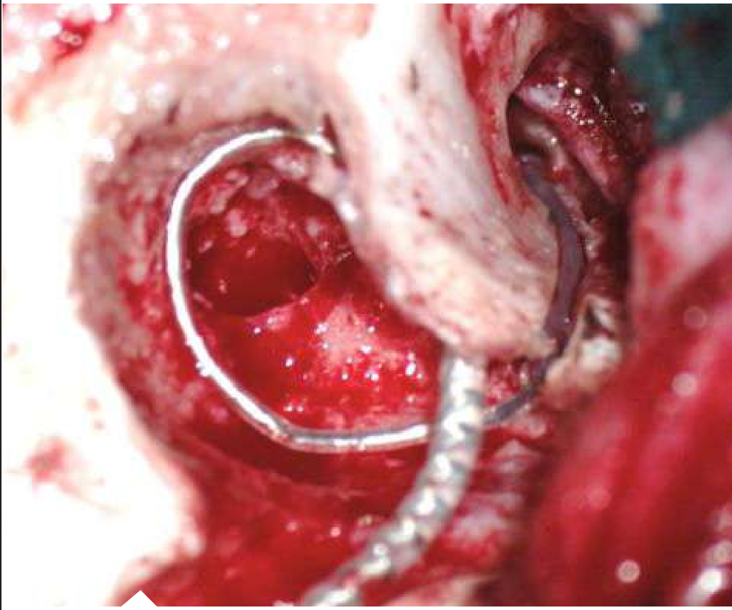

Fig.7.190. EMAC. Pediatric mastoidectomy without antrostomy. Modified technique for children.

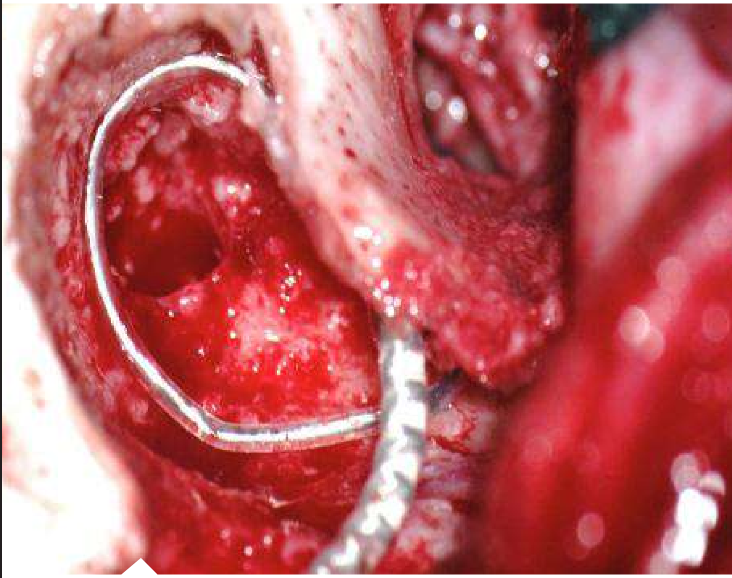

Fig. 7.191. EMAC. Electrode guide incide the small mastoidectomy. The cleft and groove have been obturated with bone paté.

EMA in ossified cochleas.

CONCEPT.

The anatomical location of the cochlea is anterior to the posterior wall of the EAC. EMA allows us to maintain this wall and to have access to any area in the cochlear turns. The maintenance of the spaces that are free of ossification allows adequate stimulation. An alternative that is possible with EMA is to do a double cochleostomy with the intention of maintaining these spaces and confirm an adequate insertion.

SISTREMATIZATION OF THE TECHNIQUE.

a. Partial ossification and double cochleostomy.

Usually the ossification is located in the basal turn, near the round window (Figs. 7.194, 7.195). In these cases the drilling is initiated from the round window in an anterior - inferior direction towards the beginning of the turn of the basal turn. It is possible to find non ossified spaces In this area and to do a cochleostomy. A second cochleostomy can be done with a 1 mm bur at the side of the first one, under the cochleariform process, at the level of the medial spira (turn) Fig. 7.197.

If a basal cochleostomy can be done, the electrode guide is inserted and then checked through the medial cochleostomy, thus making sure that the electrodes are correctly positioned. This maneuver is particularly useful when intraoperative radiology is not available. Figs.7.196, 7.198, 7.199.

If the insertion of the electrode guide would not be posible from the basal turn, a reversed insertion can be done from the cochleostomy of the medial turn, in direction towards the round window. It is not necessary to sacrifice the ossicular chain which serves as an anatomical landmark. Double cochleostomy allows a safe insertion when it is done from the basal turn. Magnetic resonance imaging is essential inthese cases. Figs. 7.192, 7.193.

b. Total ossification.

EMA allows a circunmodiolar technique in order to completely expose the basal turn. This implies the elimination of the medial tur and apical turns, conserving the posterior wall of the EAC. The ossicular chain must be sacrificed in order to place the tympano meatal flap as anterior as possible. The tensor tympani muscle is sectioned as well as the malleus head maintaining its handle, since this allows stabilization of the tympanic membrane once the flap has been replaced.

EMA IN TEMPORAL BONE MALFORMATIONS.

The potential benefit of EMA is maximized when there are malformations with a bifurcated facial nerve or a facial nerve with an anomalous tract. In these cases the risk of damaging the nerve by a posterior tympanotomy approach is high,

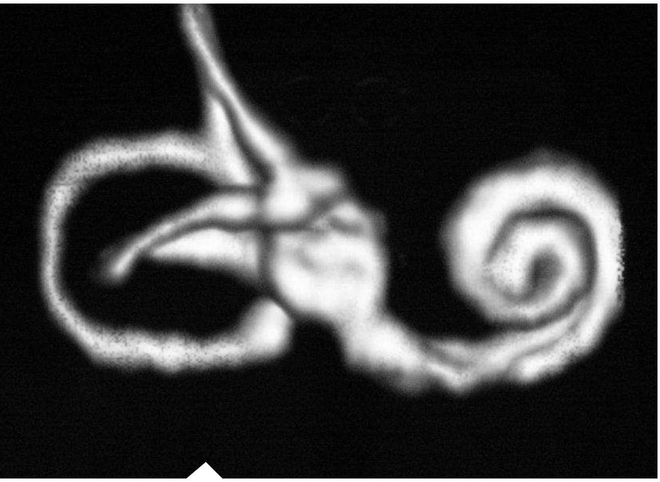

Fig 7.192. Otosclerosis.Cochlea with permeable scalas. Inst. Rx Dra Guirado, Barcelona.

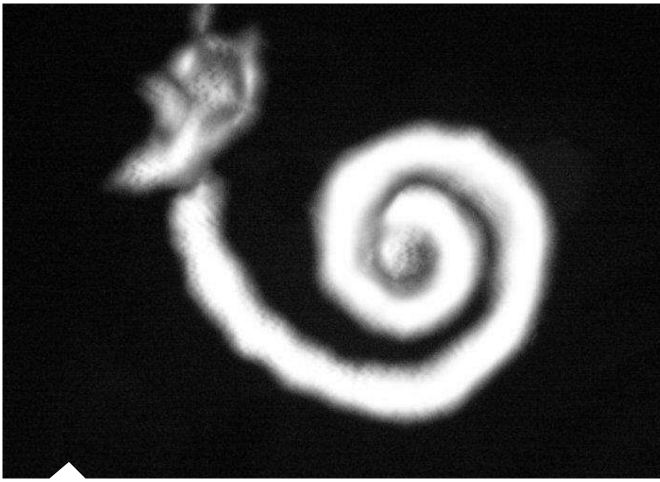

Fig 7.193. Otosclerosis. Labyrinthitis ossificans post sptapedectomy. Only the scala tympani can be observed. Inst Rx Dra Guirado, Barcelona.

Fig 7.194. CAT Scan. Stapedectomy prostheses and otospongiosis.Inst. Rx Dra Guirado, Barcelona.

Fig 7.195. CAT scan. Otospongiosis that involves the basal turn and allows the CI (Figs 7.197. and 7.198). Inst Rx Dra Guirado, Barcelona.

Fig.7.196. EMA. Technique for partial ossification. Dissection of a left temporal bone. The middle turn has been completely exposed in order to observe the final position of the electrode array.

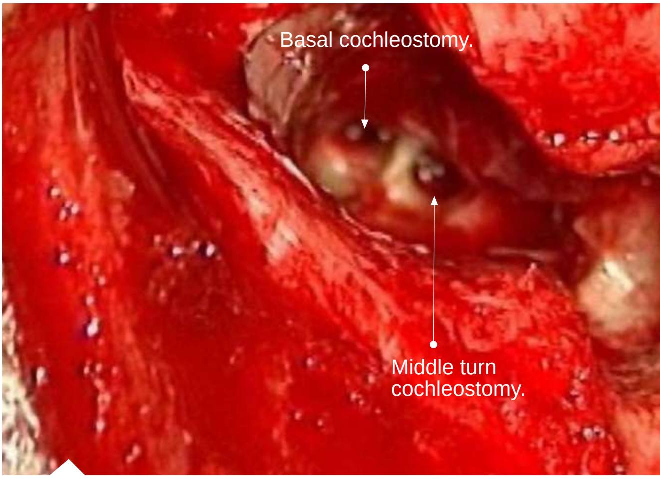

Fig. 7.197. EMA. Technique for partial ossification. Double cochleostomy: basal and middle turn.

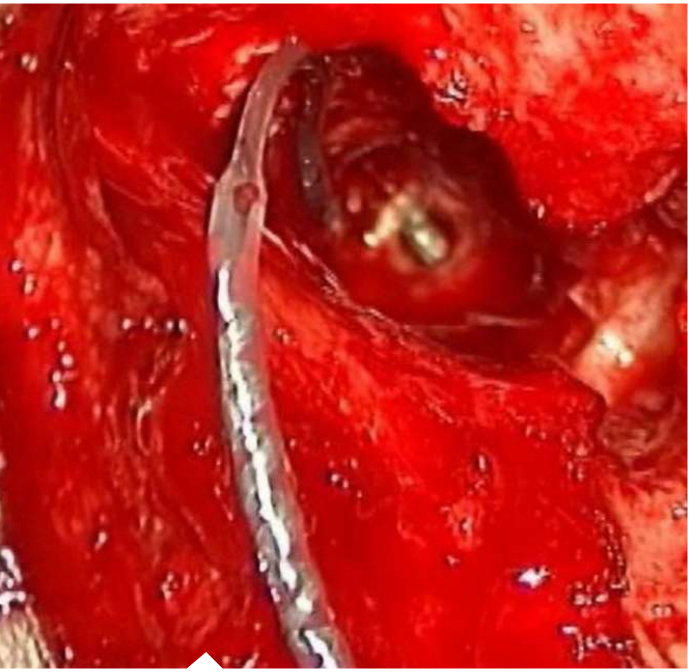

Fig 7.198. EMA. Technique for partial ossification. The electrodes are inserted by the basal turn and their position is checked in the middle turn.

whereas in the approach by the ear canal the risk is significantly diminished. In congenital malformations identified with an adequate CAT scan, a cochleostomy via an endomeatal approach can be done without the risk of damaging the facial nerve.

Hidden dangers.

Cochlear implant surgery is not without some risks, and these are more related to the surgical technique than to the pathology. Cochlear implant surgery is usually done in an anatomically normal ear, therefore, the surgical risks should be minimal. What matters most is not how it is positioned but how it works over time after it has been adequately positioned.

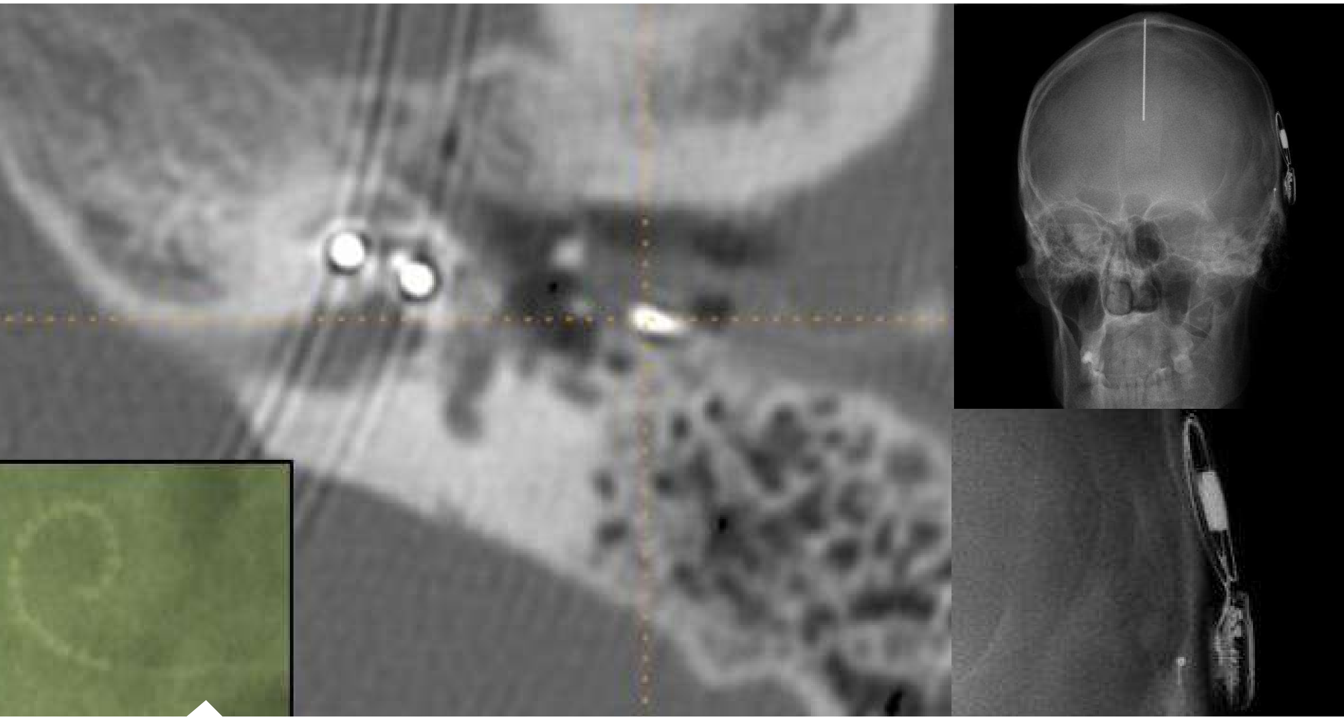

Fig 7.199. EMA technique for partial ossification. Post op control with CAT scan.

FACIAL NERVE LESION.

The main risk of this surgery is damaging the facial nerve. EMA significantly reduces this chance, since its approach to the middle ear is through the EAC and through this natural opening the intratympanic portion of the facial nerve can be identified without any drilling. This is one of the main advantages of EMA since the best way to avoid damage of the facial nerve is to identify exactly its location.

Posterior tympanotomy requires skeletonization and at times exposure of the facial nerve. A lesion can thus be caused by direct damage or by heat produced by the bur near the Falopian canal. Fayad et al (8), described 0.7% delayed onset of facial paralysis in a retrospective study of over 700 cases. The cause of this paralysis is not clear, however, it is likely that this represents an inflammatorey post surgical process or a reactivation of a viral process related to microtrauma over the fallopian canal or chorda tympani. In EMA, the facial canal and chorda tympani can be easily identified

EMA does not require searching for the nerve; it identifies it without drilling. As a difference from posterior tympanotomy, the nerve is not an anatomical reference for EMA. Facial nerve monitorization is unnecessary in normal ears. The only anatomical reference to the facial nerve in normal ears for EMA is its branch chorda tympani which can be preserved with EMA since this technique intends to be the least destructive that is possible.

INTERNAL CAROTID ARTERY.

The carotid artery is very close to the basal turn. This proximity has to be considered as well as its anatomical variations (see anatomy chapters) Figs 7.200, 7.201.

Fig. 7.200. Relationship of the basal turn of the cochlea and the carotid artery Inst Rx Dra Guirado, Barcelona.

Practical suggestions.

POSTERIOR WALL.

Regardless of the surgical approach, cochlear implant surgery is subjected to limited anatomical spaces. In the case of posterior tympanotomy the opening of the facial recess is not always sufficient in order to expose the round window adequately. At times extensive drilling is required. EMA uses the EAC which is anatomically less limited than posterior tympanotomy. The natural access to the area of the windows is via the EAC. That is why stapes surgery is done by an endomeatal and not a posterior tympanotomy approach. Exposure of the round window is always possible through the endomeatal approach. This is not the case with posterior tympanotomy. Posterior tympanotomy is not feasible in cases of a low tegmen or a prominent lateral sinus. In these cases removal of the posterior wall and closure of the EAC is required. Fig. 7.202.

Fig 7.201. Temporal bone dissection. Anatomical relationship of the basal turn and he carotid artery. Courtesy of Prof. Dr Rodrigo Posada Trujillo. Centro Asociado de la FIMF in Pereira, Colombia.

EMA can position the electrode array in the same plane of insertion than the posterior tympanotomy, without damaging functional structure, whereas this is not possible with posterior tympanotomy.

Fig. 7.202. Prominent lateral sinus that does not allow a posterior tympanotomy. Inst Rx Dra Guirado, Barcelona.

ROUND WINDOW.

The round window has gradually acquired more relevante as the insertion site for the electrode array, since it is the natural ostium where the scala tympani starts. The same as the oval window, it has anatomical variabilities. Moreover, the niche is usually covered by a mucous layer (false round window membrane) that has to be identified and removed.

Procedure.

MASTOID AIR CELL SYSTEM (MACS).

EMA preserves healthy tisúes and does not destroy the MACS (18) which allows gas diffusion and contributes to maintaining the pressure of the middle ear. MACS acts as a compensation element for the ventilation of the middle ear (17) and this helps in avoiding inflammatory processes and in the development of a mastoid aeration system for a neumo-sufficient tympanomastoid complex (20).

More alterations of ventilation of the middle ear seem to occur with tympanomastoidectomy than with tympanoplasty alone (22). Electro acoustic stimulation with a hybrid implant requires not only of residual hearing but also a correct function of the middle ear. Mastoidectomy could have a negative influence in the functional results originating an additional conductive loss (23). EMA has less blood loss, and in addition EMA allows maintenance of the MACS (Fig. 7.203).

Beyond the consequences that such destruction implies, a surgical approach should always intend to maintain healthy tissues, not only because it simplifies surgical technique but because it minimizes surgical aggression to the patient.

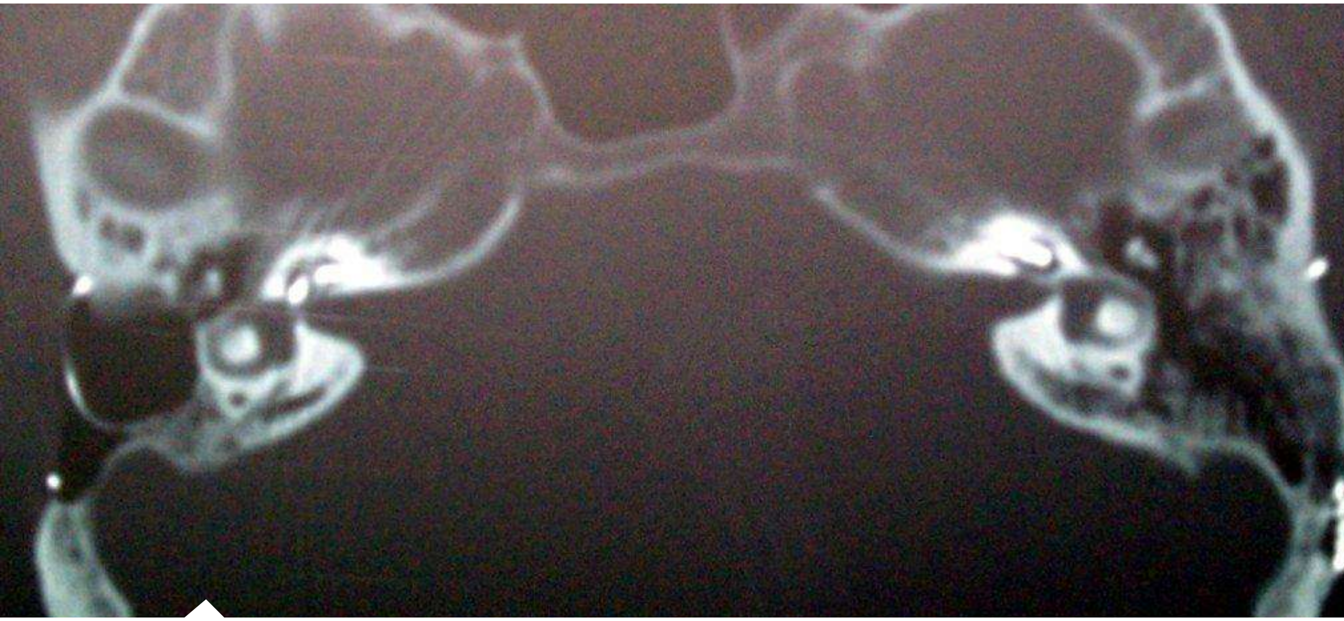

Fig. 7.202. Bilateral cochlear implantation. Comparing EMA and posterior tympanotomy. Note the mastoidectomy in PT compared to mastoid preservation with EMA.

ANGLE OF INSERTION THROUGH THE ROUND WINDOW.

EMA has a better angle of insertion that the facial recess, which is a narrow anatomical window which requires drilling of margins or to perform a promontorial cochleostomy (15), and even then it does not avoid -in all cases- damage to the spiral lamina, basilar membrane or stria vascularis (3, 4, 21). In EMA the electrode guide is introduced through the EAC in front of its posterior wall, instead of introducing them behind this wall, following an insertion line that from a more anterior and superior position. This insertion line is directed toward the floor of the basal turn, avoiding trauma to the spiral lamina making its introduction easier (Figs. 7.204, 7.205). Insertion is soft and generally there is no need to drill the margins of the round window, thus avoiding the introduction of bone dust and/or blood in the scala tympani. EMA is an adequate approach for the preservation of residual hearing (EAS-"soft surgery") (11).

ALSE ROUTES.

EMA avoids false routes because it allows easy recognition of the round window ans scala tympani. This adequate view avoids confusion with hypotympanic air cells.

Fig 7.204. Dissection. Endocochlear view of the natural projection of the basal turn (red line). Courtesy of Prof. Rodrigo Posada Trujillo. Centro Asociado de la FIMF in Pereira, Colombia.

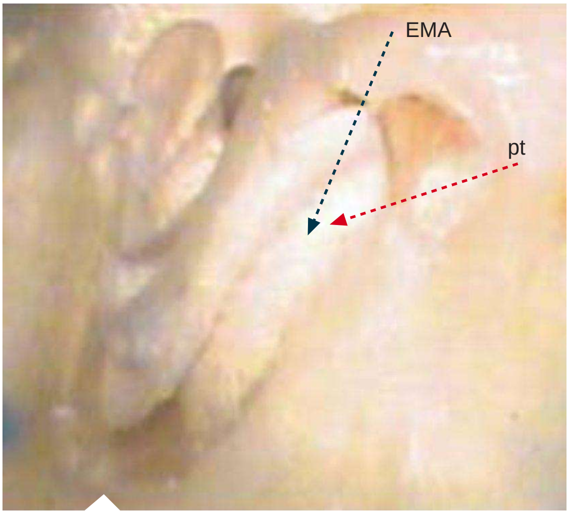

Fig. 7.205. Dissection. Angle of insertion for EMA and posterior tympanotomy (pt). Courtesy of Prof Dr Rodrigo Posada Trujillo. Centro Asociado de la FIMF in Pereira, Colombia.

BETTER STIMULATION.

Insertion through the round window allows better stimulation of the neuronal population because the position of the electrode array is done exactly at the beginning of the scala tympani.

TYMPANOTOMY.

Adequte visualization of the round window is not posible in one third of the cases through posterior tympanotomy. For this reason Goycoolea and Lavinsky (12, 13) in addition to a limited posterior tyumpanotomy do an anterior tympanotomy. Anterior tympanotomy is inherent to EMA, therefore, both tympanotomies are not necessary.

CONTRAINDICATIONS.

There are no absolute contraindications. Those cases with a small EAC or with prominent osteomas can require a previous surgical procedure. Dermatologic pathologies that involve the ear canal have to be considered.

Results.

SURGICAL.

Follow upfor over 3 years of patients subjected to EMA has shown no complications. Healing of the EAC and retroauricular incision was adequate. There have been no electrode extrusions in the EAC and the skin is normal. Two of 30 cases required a marginal cochleostomy (3).

Annual radiologic controls show stability of the system over time (Figs 7.208, 7.209).

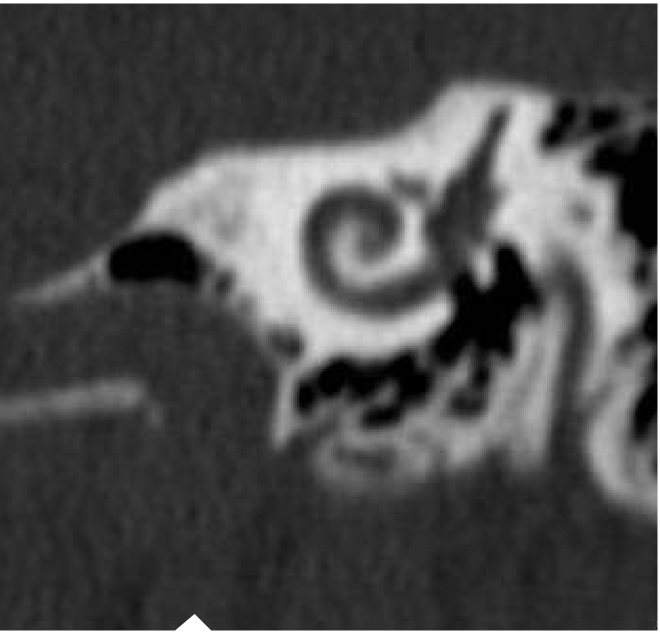

Fig 7.206. CAT scan. Insertion plane for EMA.

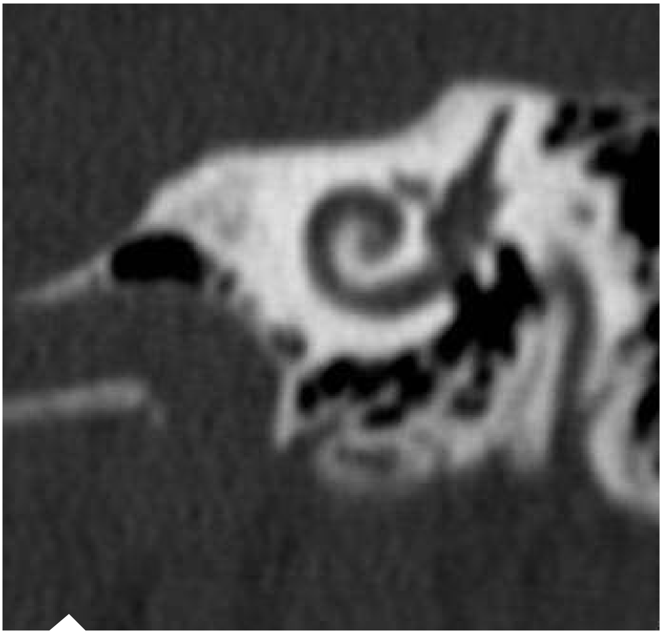

Fig 7.207. CAT scan. Stress points of the insertion plane of the posterior tympanotomy. Circle indicates promontorial cochleostomy.

Fig 7.208. EMA. Rx Stenvers. The electrode array can be observed traversing the EAC and inserted in the cochlea.

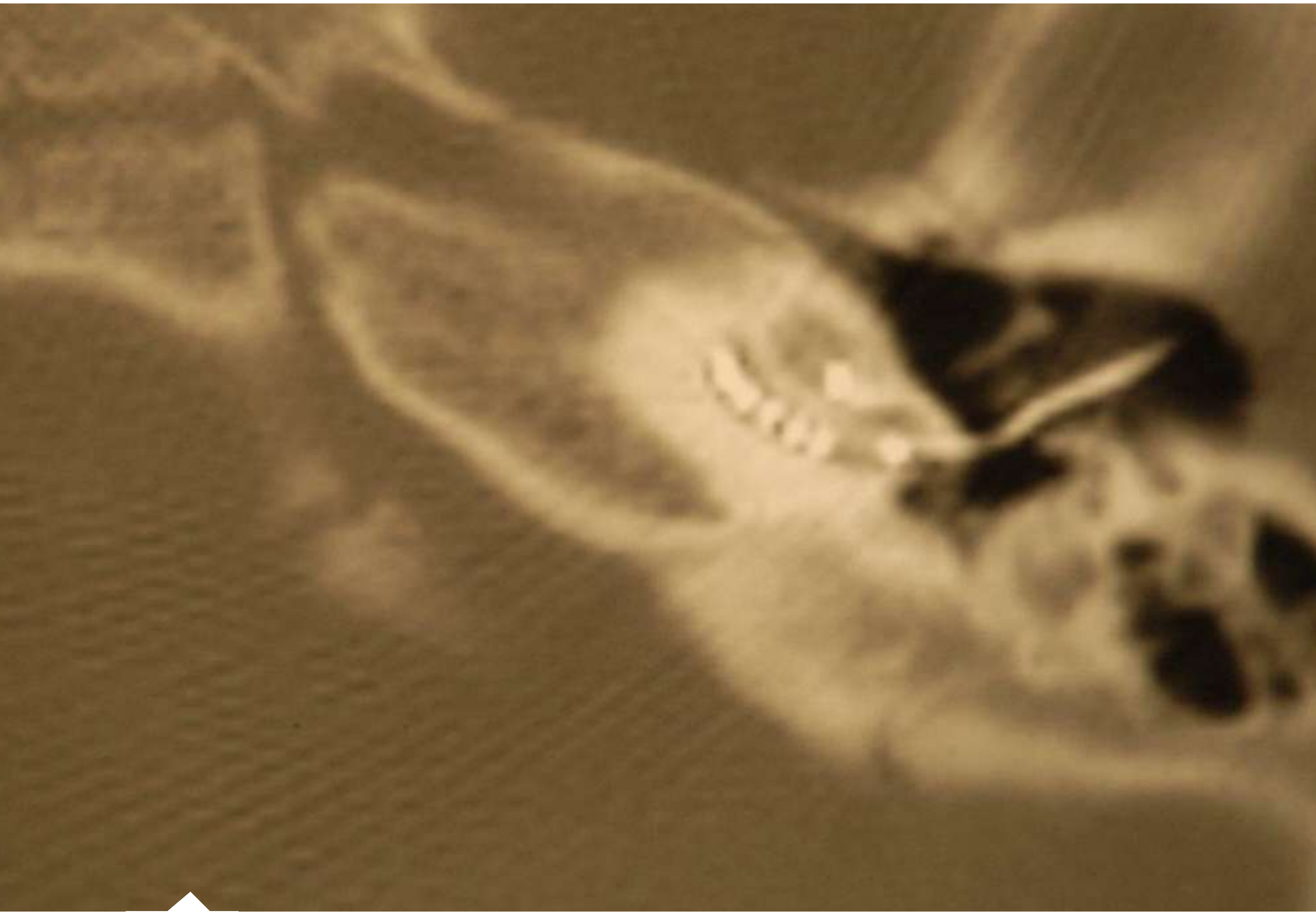

Fig 7.209. EMA. Patient was implanted at 18 months of age. Control at 3 years that shows stability of the implant and adequate position of the electrode array.

Potential complications and how to avoid them. Extrusion

The main objections to the approaches that use the EAC for CI is the possibility of extrusion of the electrode guide through the skin of the EAC. This complication was described in previous attempts of approach through the EAC (14, 15). This possibility is avoided with EMA because of the lip that is left over the groove and the bone paté that isolates the electrode guide from the skin.

Postoperative management.

Retroauricular sutures and EAC packing are removed 7 to 10 days after surgery. The patient is checked on a weekly basis and the hook up is done at 4 weeks.

Conclusions.

The purpose of this technique is to avoid antromastoidectomy, posterior tympanotomy and promontorial cochleostomy, since these are replaced by the groove and insertion through the round window. This is s fast and safe technique that avoids osseous demolition and avoids damage to the facial nerve. The ossicular chain and chorda tympani are preserved and the endomeatal exposure of the round window facilitates the insertion of the electrode array into the scala tympani. It can replace the transmastoid approach in normal cochleas and in previously operated patients. It can also be used in malformed cochleas, ossified c ochleas and even in cases with anatomical variations. It is also a surgical option when posterior tympanotomy cannot be done.

EMA reduces surgical time with the same functional result. It is an alternative technique that can also be a first choice.

Acknowledgements.

Our thanks to Dr Carmen Guirado and Dr Pedro Martínez of the Institutes of Rx and RM Dra Guirado de Barcelona (España) for their collaboration.

References

1. Clark GM, Pyman BC, Bayley QR. The surgery for multiple electrode cochlear implantations. J Laryngol Otol 1979; 93: 215-28

2. Escudé B, James C, Deguine O, Cochard N, Eter E, Fraysse B. The size of the cochlea and predictions of insertion depth angles for cochlear implant electrodes. Audiol Neurotol 2006;11 Suppl 1:27-33.

3. Roland PS, Wright CG, Isaacson B.Cochlear implant electrode insertion: the round window revisited. Laryngoscope. 2007 Aug;117(8):1397-402

4. Briggs RJ, Tykcinsky M, Stidham K, Robertson JB. Cochleostomy site: implications for electrode placement and hearing preservation. Acta Otolaryngol. 2005 Aug;125(8):870-6

5. Gstoettner WK, Hamzavi J, Baumgartner WD, Czerny CC Fixation of the electrode array with bone paté in cochlear implant surgery. Acta Otolaryngol. 2000 Mar;120(3):369-74.

6. Li PM, Wang H, Northrop C, Merchant SN, Nadol JB Jr. Anatomy of the round window and hook region of the cochlea with implications for cochlear implantation and other endocochlear surgical procedures. Otol Neurotol. 2007 Aug;28(5):641-8.

7. Hamamoto M, Murakami G, Kataura A. Clin Anat 2000; 13(4):251-6. Topographical relationships among the facial nerve, chorda tympani nerve and round window with special reference to the approach route for cochlear implant surgery

8. Fayad JN, Wanna GB, Micheletto JN, Parisier SC. Facial nerve paralysis following cochlear implant surgery . Laryngoscope. 2003 Aug;113(8):1344-6.

9. Schindler RA. Surgical consideration for multichannel cochlear implants. In Schindler RA, Merzenich MM eds. Cochlear Implants. Raven Press, New York. 1985; 417-20

10. Banfai P., Kubic S, Hortmann G. Out extra-scala oerating method of cochlear implantation. Experience with 46 cases. Acta Otolaryngol Suppl (Stockh) 1983; 411: 9-12.

11. Cohen NL. Cochlear implant soft surgery: fact or fantasy? Otolaryngol Head Neck Surg 1997 Sep; 117(3):214-6

12. Skarzynski H, Lorens A, Piotrowska A, Anderson I. Preservation of low frequency hearing in partial deafness cochlear implantation (PDCI) using the round window surgical approach Acta Otolaryngol. 2007;127 (1):41-48.

13. Goycoolea MV, Ribalta GL. Exploratory tympanotomy: an integral part of cochlear implantation. Acta Otolaryngol. 2003 Jan;123(2):223-6

14. Schindler RA. Surgical consideration for multichannel cochlear implants. In Schindler RA, Merzenich MM eds. Cochlear Implants. Raven Press, New York. 1985; 417-20

15. Banfai P., Kubic S, Hortmann G. Out extra-scala operating method of cochlear implantation. Experience with 46 cases. Acta Otolaryngol Suppl (Stockh) 1983; 411: 9-12

16. Hausler R. Cochlear implantation without mastoidectomy: the pericanal electrode insertion technique. Acta Otolaryngol 2002; 122: 715-719.

17. The mastoid as a functional rate-limiter of middle ear pressure change. Doyle WJ. Int J Pediatr Otorhinolaryngol. 2007 Mar;71(3):393-402.

18. Preliminary results in cochlear implant surgery without antromastoidectomy and with atraumatic electrodeinsertion:the endomeatal approach.Victor Slavutsky ,Luis Nicenboim Eur Arch Otorhinolaryngol DOI 10.1007/s00405-008-0768-8 © Springer-Verlag 2008-Online version

19. Técnica alternativa a la cirugia del Implante coclear.Abordaje endomeatal.Victor Slavutsky,Luis Nicenboim.Anales otorrinolaringológicos del Perú. Vol 15,Nº1(9-18)2008 Indexada en Latindex

20. The growth rate and size of the mastoid air cell system and mastoid bone: a review and reference.Cinamon U. Eur Arch Otorhinolaryngol. 2009 Jun;266(6):781-6. Epub 2009 Mar

21. Combining perimodiolar electrode placement and atraumatic insertion properties in cochlear implantation / fact or fantasy? O.Adunka,Pillsbury,Kieffer Acta Oto-Laryngologica ,2006

22. The effect of mastoid surgery on atelectatic ears and retraction pockets.AvrahamS,Luntz M,Sadé J Eur Arch Otorhinolaryngol. 1991;248(6):335-6.

23. Mastoid buffering properties: I. Gas partial pressures. Raveh E, Sadé J, Mover-Lev H, Guney S. Ann Otol Rhinol Laryngol. 1999 Aug;108(8):750-5.