The Zone-Based Approach for Selection of Tympanoplasty Technique

Wybór techniki tympanoplastyki w zależności od lokalizacji ubytku błony bębenkowej

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SUMMARY

At the outset of surgery, the extent of a tympanic membrane defect is judged including any additional loss of area that may result from disease extirpation or removal of the mucocutaneous junction. There are, three tiers of complexity when deciding upon which technique should be used for repair. Limited central perforations are defects amenable to a standard underlay technique. The Zone Based Approach is applied for marginal perforations whereby the specific technique is selected based on the zone of the defect. The zones and specific techniques are detailed. There are however, still a significant number of patients who have scarce residual tympanic membrane, or keratin matrix adherently involving the undersurface requiring sacrifice. These situations prove poor for either standard underlay or the zone based techniques. The total tympanic membrane reconstruction (TTMR) technique was developed specifically to avoid these complications as well as facilitate extirpation of the more extensive inflammatory and neoplastic pathologies commonly encountered, yet still amenable to intact canal wall mastoidectomy approaches.

Hasła indeksowe: tympanoplastyka, perforacja błony bębenkowej, technika tympanoplastyk

Key words: tympanoplasty, tympanic membrane perforation, tympanoplasty technique

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Definitions

Standard Underlay Technique: The tympanic membrane is raised along with a few millimeter margin of ear canal skin (a tympanomeatal flap) so that a piece of grafting material (most commonly temporalis muscle fascia) may be placed beneath the membrane so that new epithelium may migrate over and seal the defect. This technique is usually limited to defects small enough so that the graft may securely bridge the gap beneath the perforation after the annular ligament and tympanomeatal flap are replaced more or less to the original position. The size of the defect appropriate for this technique should be judged after removal of the mucocutaneus junction that has formed at the rim of the perforation.

Zone-Based Approach: A system for categorizing techniques used to repair the tympanic membrane based on location or 'zone' of the defect (Fig. 1). The techniques are detailed in this presentation.

Total Tympanic Membrane Reconstruction: A technique of total reconstruction of the tympanic membrane. The method uses a large free epithelial graft taken from the anterior canal wall skin, locally obtained split thickness skin grafts and a specific method of stenting during the healing process. The details of the procedure are presented in this presentation. It differs from overlay grafting insomuch that the annulus is removed, which allows for an unhindered access to the mesotympanum for disease extirpation. It is useful for both inflammatory and neoplastic processes. It can be easily performed in a single stage or combined with either immediate or delayed ossiculoplasty.

Purpose

At the outset of surgery, the extent of the tympanic membrane defect is judged including any additional loss of area that may result from disease extirpation or removal of the mucocutaneous junction (i.e. rimming).

There are in summary, three tiers of complexity when deciding upon which technique should be used for repair.

I Limited Central Perforations: defects amenable to a standard underlay technique.

II Marginal Perforations: defects benefiting from the Zone Based Approach whereby the specific technique is selected based on the zone of the defect.

III Total Tympanic Membrane Reconstructions (TTMR): total or subtotal defects.

Limited central perforations can be easily managed with standard underlay technique. This technique is usually limited to defects small enough so that the graft may securely bridge the gap beneath the perforation after the annular ligament and tympanomeatal flap are replaced more or less to the original position. The

size of the defect appropriate for this technique should be judged after removal of the mucocutaneus junction that has formed at the rim of the perforation.

For the more complex and larger marginal defects, the Zone Based Approach serves as a model for planning and execution. The concept of 'zone' may be conceptualized as the region where the defect approaches the annular margin. These zones have been selected to highlight the different specific technical requirements for repair while minimizing common failure mechanisms. Each zone is presented with idealized technical details to ensure safe, reliable execution and consistency of outcomes.

There are however, still a significant number of patients who have scarce residual tympanic membrane, or keratin matrix adherently involving the undersurface requiring sacrifice. These situations prove poor for either standard underlay or the zone based techniques. Other techniques involving grafting lateral to the tympanic annulus have been described to better handle these situations [1, 2]. However, these techniques can result in delayed epithelialization of exposed canal wall bone and mucosalization of the neotympanum. Techniques that involve grafting lateral to the tympanic annulus may also result in intratympanic cholesteatoma formation [3]. Repair of large perforations involving and including the anterior segment additionally predisposes to anterior blunting as well as graft lateralization [4]. The total tympanic membrane reconstruction (TTMR) technique was developed specifically to avoid these complications as well as facilitate extirpation of the more extensive inflammatory and neoplastic pathologies commonly encountered, yet still amenable to intact canal wall mastoidectomy approaches [5].

Principle

The Zone Based Approach provides the operator with options to repair defects based on the zone of the marginal perforation. The techniques were developed to combat common failure mechanisms for each zone.

TTMR was developed to completely reconstruct the tympanic membrane utilizing a combination of anterior canal wall free skin graft, split thickness skin grafts taken from the post-auricular incision and a scaffold of either temporalis fascia or other adequate substrate. The technique also relies on anterior canal wall stenting. The technique differs from lateral onlay techniques in that the entire fibrous annulus and fibrous tympanic membrane remnant need not be retrained so that complete access to the middle ear cavity can be accessed and/or reconstruction can be performed in any circumstance where the canal wall is kept intact. The procedure can be performed with any combination of ossicular chain, and with either immediate or delayed ossiculoplasty and/or cartilage tympanoplasty.

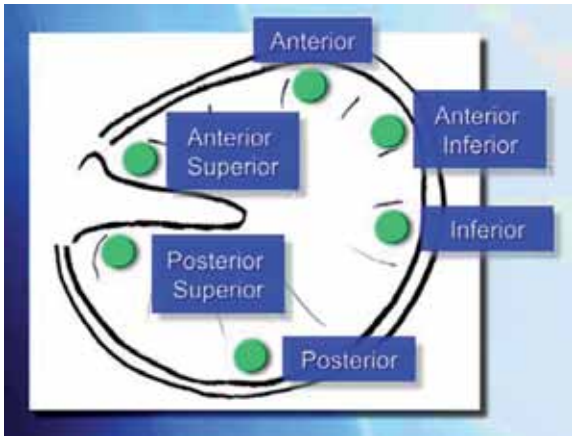

Fig. 1. Zone Based Approach: The six "zones" may be conceptualized as regions where a tympanic membrane defect approaches the annular margin. These zones have been selected to highlight the different specific technical requirements for repair while minimizing common failure mechanisms. Each zone is presented with idealized technical details to ensure safe, reliable execution and consistency of outcomes.

Indications

Tympanoplasty is most commonly performed with or without mastoidectomy to treat the sequelae of chronic suppurative otitis media (CSOM) with perforation or after extirpation of cholesteatoma or other benign processes. Some cases of CSOM resolve with medical therapy and dry ear precautions. If the patient is asymptomatic or elderly, then consideration may be given to observation and expectant management. Younger healthy patients are typically advised to undergo elective repair to avoid further sequelae and shield the middle ear from further risk of repeated inflammation and potential complications. The decision to undergo surgery is often prompted by recurrent otorrhea, or if the patient is handicapped by a residual conductive hearing loss [6].

The specific techniques are selected according to the Zone Based System detailed below. The indications are dictated by zone or region of perforation. Smaller central perforations can be addressed by standard underlay described above. Larger, total or subtotal defects should be repaired using the TTMR technique.

Indications for TTMR include total perforations, large subtotal perforations with full anterior marginal extension, subtotal perforations with mucosalization or refractory granular inflammation of the tympanic remnant, or cholesteatoma adherently involving a significant portion of the TM undersurface.

Contraindications

Relative contraindications for surgery are based largely on medical co-morbidities and/or stable longstanding dry perforations with little or no impact on hearing.

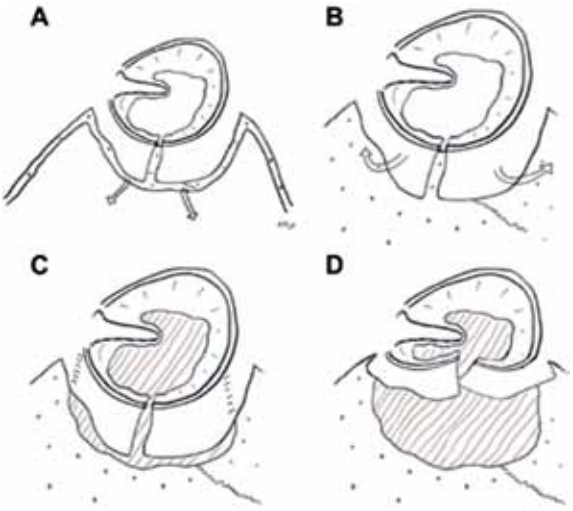

Fig. 2. Posterior Zone Surgical Technique – Posterior Annular Split with Advancement: A. A tympanomeatal flap is fashion with a 4–5 mm margin. B. The Keorner's flap is elevated and the tympanomeatal flap is sectioned into a superior and inferior rotational flap. C. The graft is introduced in an underlay fashion. D. Limited incisions are made at the bases of the flaps to facilitate anterior advancement and hasten epithelialization of the neotympanum by reducing the uncovered surface area. The graft should track back along the posterior canal wall sufficiently so that the Koerner's flap can make contact and act as a conduit for reepithelialization and reduce the risk of delayed bone exposure.

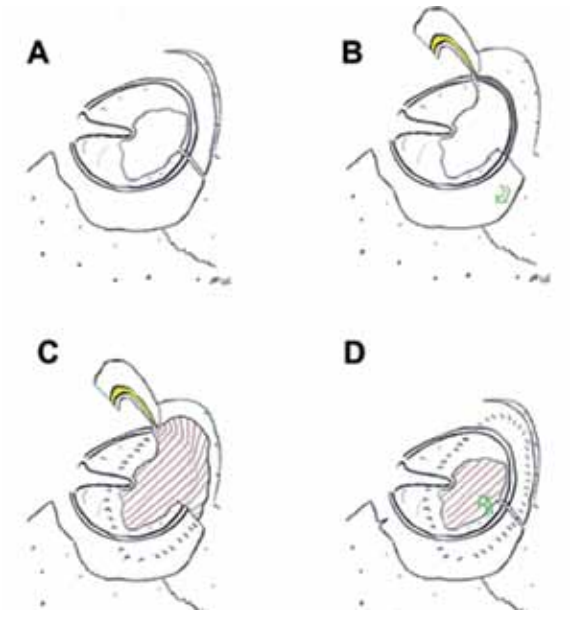

Fig. 3. Inferior Zone Surgical Technique – Inferior Annular Split: A. The tympanomeatal flap is extended anteriorly and the annulus is split creating and anterior and posterior flap. B. The flaps are raised. C. The graft is positioned. D. The posterior limb is advanced.

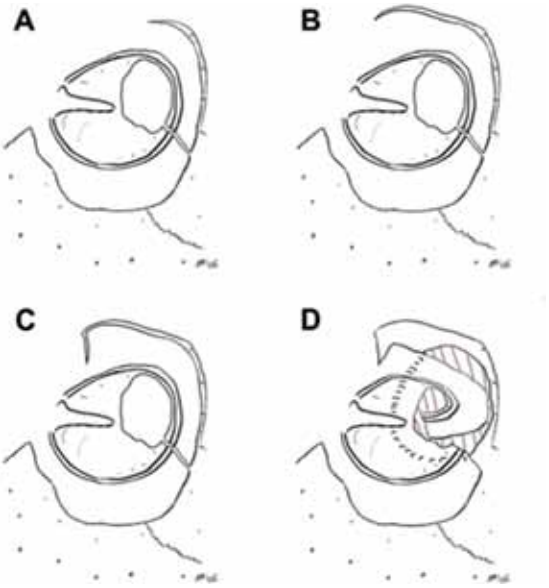

Fig. 4. Anterior Inferior Zone Surgical Technique – Extended Inferior Annular Split with Advancement: A&B. After elevation of a Keorner's flap, a canal incision is carried along the inferior to anterior canal wall beyond the location of the perforation. C. A back cut is created to facilitate rotation of the pedicle over the defect. D. Graft in proper position and flap rotated in place.

As well as patient's desire not to undergo elective treatment. This assumes a fair presentation of the risk benefit ratio and compliance with conservative measures including dry ear precautions and appropriate monitoring.

Zone Based Approach

Posterior Zone Surgical Technique – Posterior Annular Split with Advancement: figure 2A reveals the largest posterior marginal defect that can reliably be addressed using the technique. The technique is detailed in figure 2A–D. With this method, the annulus is split and tympanomeatal flaps are rotated forwards towards the neotympanum to provide epithelial coverage and hasten the healing process. It is advisable to use a graft long enough to reach back up the posterior ear canal so that the Koerner's flap may make contact. This will aid in re-epithelialization of the region from where the flaps were advanced.

Inferior Zone Surgical Technique – Inferior Annular Split: figure 3 details the technique used to repair an inferior perforation. The technique is greatly facilitated by performing a canalplasty. While much has been written about anterior blunting, little is discussed regarding inferior blunting. If the inferior tympanic hump is lowered so that the graft traverses onto the bony annulus with as flat an angle as possible, the scar build up will be minimized and the effective surface area of the neotymanum will be maximized. An inferior

annular split technique assumes an adequate anterior remnant. It has been our preference in this setting to advance the posterior limb (Fig. 3D) and allow the anterior annulus to compress the graft into position. This is in contrast to the repair of the Anterior Inferior Zone, which will benefit from rotating the larger anterior limb in order to encourage early epithelial coverage and hasten healing in this vulnerable area (Fig. 4D).

Anterior Inferior Zone Surgical Technique – Extended Inferior Annular Split with Advancement: figure 4 details the surgical technique used to repair an anterior inferior perforation. This is a common perforation seen as a chronic sequela of failed closure of ventilation tube placed during childhood. Similar to inferior zone, the ease and effectiveness of this technique is greatly enhanced by canalplasty. The technique differs from the inferior zone in that the incision is carried further anteriorly along the canal wall. Because the anterior mesotymanum is deeper inadequate support may result in graft collapse. It is important to provide sufficient elevation of the anterior annular ligament to create a secure hold for the graft. The anterior flap is rotated to provide coverage and hasten epithelialization. This repair can be supported as well with a thin cut cartilage laid under the graft and solid lateral packing with antibiotic saturated 1/8 inch cotton strips to minimize blunting. The placement of gelatin sheet film in the anterior mesotympanum also provides a stable substance against which to pack and prevent medial collapse of the cartilage and graft.

Anterior Zone Surgical Technique – Anterior Pull-tab: figure 5 details the surgical technique used to repair a primarily anterior perforation. This may be seen as a result of a technically inadequate past prior attempt at repairing a too anterior defect by standard underlay. The pull-tab technique is designed to provide adequate support of the graft onto the bony annulus, while also reducing the negative effects of anterior blunting. The pull-tab technique involves the minimum displacement of the residual annular ligament, which can inherently provide a stable support. While, it is possible to place a graft as an underlay through an anterior elevation, the necessary wide elevation of the annulus may result in undesired blunting. Pull-tab can be performed with either a circumferential canal wall skin incision if a canalplasty is planned (as shown in figure 5). Otherwise a conventional posterior tympanomeatal flap may be fashioned with the addition of a separate limited anterior access incision. In either case, a 'pull tab' is fashioned on the anterior edge of the graft (Fig. 5D) and introduced from the posterior opening. The ossicular chain can be examined in this manner as well. The adjunctive measures to optimize packing and stability mentioned above can be employed as well. If there is a considerable amount of anterior annular separation, an external silicone stent may be placed in the ear canal.

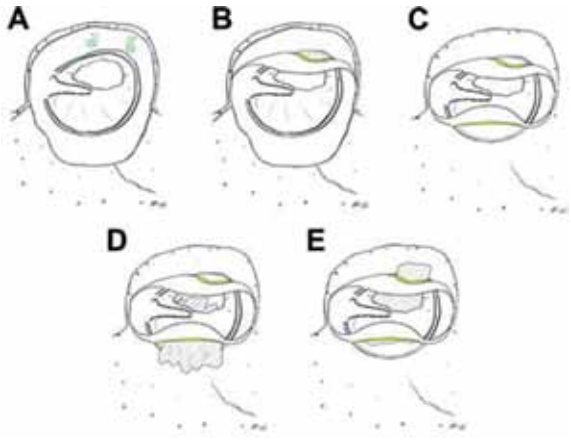

Fig. 5. Anterior Zone – Anterior Pull Tab Technique. A. A circumferential incision provides access to both an anterior and posterior annular elevation. B. A limited elevation of the anterior annular ligament is performed exposing the middle ear mucos (green dotted line). This is sharply incised to allow access for snagging the pull tab out of the middle ear. C. A standard posterior tympanomeatal flap is raised. D and E. The graft with cut tab is introduced through the posterior opening, pulled up and secured onto the anterior bony canal wall. A fine right angle pick slightly bent is ideal for this maneuver.

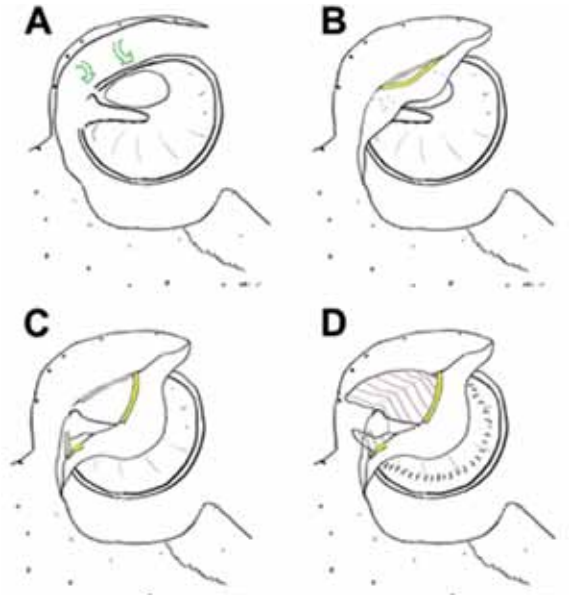

Fig. 6. Anterior Superior Zone – Anterior Superior Pull Through. A. After fashioning a Koerner's flap, an incision is exteneded along the anterosuperior canal wall. B. The annular ligament is separated providing access for grafting. C. The flap is separated from the short process and upper malleus handle to create a gap for pull through of the graft. D. The graft is introduced anterior to the malleus. A lip is pulled under the malleus through the posterior gap to secure it in place as shown.

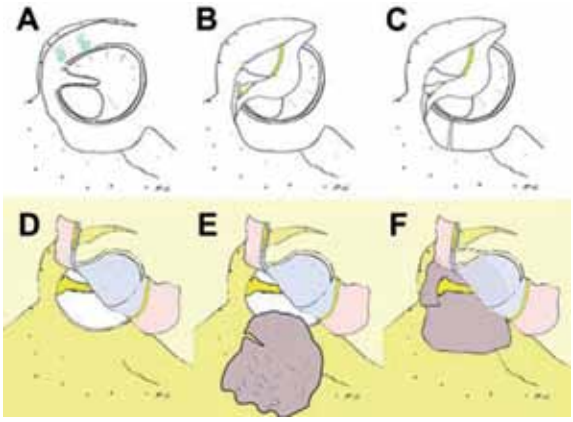

Fig. 7. Posterior Superior Zone – Posterior Superior Tympanoplasty with Malleus Wrap. A&B. A superior tympanomeatal flap is raised to create access both anterior and posteriorly with separation of the tympanic membrane from the malleus. C. The flap is split posteriorly to gain wide access. D. The flaps are raised. E&F. The graft is introduced from posteriorly and wrapped around the malleus as shown

Fig. 8. A Cross-sectional schematic of incision placement. Single arrow demarcates lateral free skin graft harvest incision placed at the bony cartilaginous junction. Double arrow demarcates long pedicled Koerner's incisions. B Transcanal schematic of free graft harvest incisions and Koerner's flap

Anterior Superior Zone Surgical Technique – Anterior Superior Pull Through: (Fig. 6) Repair of a perforation on the anterior border of the malleus may heal with either a residual perforation or epithelial tract immediately in front of the malleus if the graft is not properly supported. The malleus and tensor tendon can direct the graft downwards if it is simply placed as an underlay from above. The Anterior Superior Pull Through technique minimizes this complication by pulling a lip of the graft under the malleus, then up and over the posterior superior bony annulus. (Fig. 6 C, D) First, the tympanic membrane remnant is carefully dissected off of the upper portion of the malleus. It is helpful to sharply incise along the back edge of the malleus handle and then connect the two pockets from back to front. The umbo should be kept intact in order to provide stabilization and prevent lateralization. (Fig. 6 C) This technique can also be used to repair limited pars flaccida defects or provide access to very

Fig. 9. Cross-sectional schematic of canalplasty. The cross-hatched area represents the region of bone removal. The black arrow denotes the resultant anterior ledge.

small congenital cholesteatomas located deep to the anterior superior quadrant. This procedure is greatly facilitated by canalplasty even limited to trimming of the tympanosquamous suture line. The graft can be introduced through the anterior superior gap, then pulled and secured posteriorly. If the ossicular chain is no longer intact, then consideration should be given to sectioning the malleus neck, severing the tensor tendon and underlaying the graft from above though the widened access.

Posterior Superior Zone Surgical Technique – Posterior Superior Tymanoplasty with Malleus Wrap: (Fig. 7) Similar difficulties arise securing the graft as described in the anterior superior zone. The obstructing presence of the malleus and its tendon can potential drive the graft medially and result in fistula or perforation. Similarly, both anterior and posterior access point can be developed as shown in the figures. In this case, we typically split the flap posteriorly as in figure 7 C and introduce the graft from this wide access. The graft should be wrapped under and back over the malleus as shown in figure 7 F. The anterior flap should then be placed over any gaps to ensure coverage and minimize failure in this region.

Total Tympanic Membrane Reconstruction – TTMR

Postauricular access to the external auditory canal is provided through a long Koerner's flap taken just lateral to the posterior tympanic annulus. This flap will provide a vascularized pedicle to the forming neo-

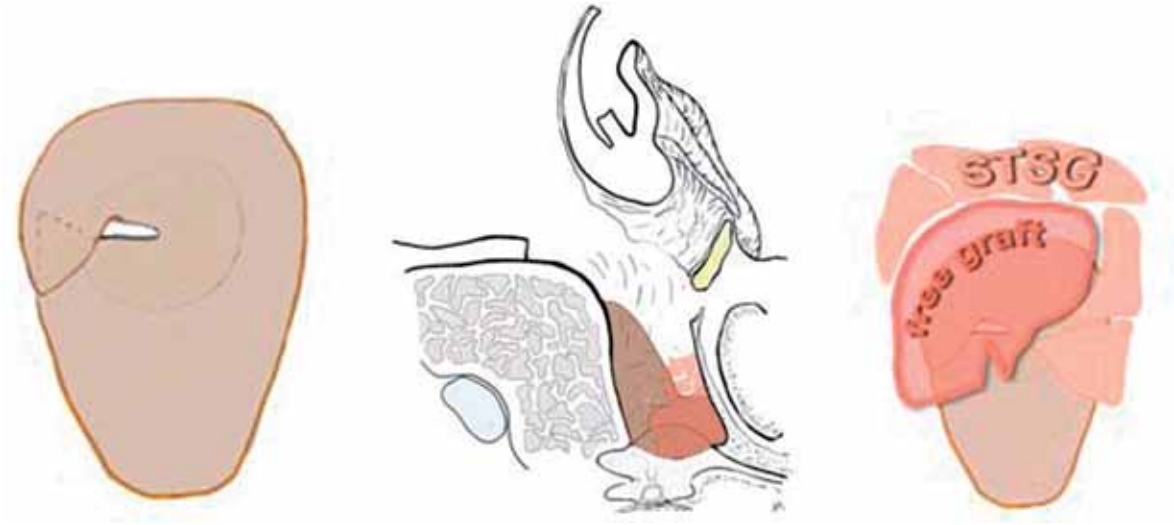

Fig. 10. A Transcanal schematic of tympanoplasty graft placed with notch for malleus handle. B Cross-sectional schematic of same. C Transcanal schematic demarcates position of free-skin and split-thickness skin grafts

tympanum. Care is taken to remove any mucosalization at the distal flap tip that may eventually grow onto the underlying graft. Neither the annulus nor any residual TM remnant is included in this flap (Fig. 8B, double arrow).

The anterior canal wall skin is harvested as a free graft. A lateral incision is made at the level of the bony cartilaginous junction so that the maximum available size is provided (Fig. 8A, single arrow). A medial incision is made just lateral to the annulus so that no mucosa cells are included in this segment. Again, the residual TM and annular remnant are not included. Adequate size is achieved by the extreme lateral position of the anterolateral incision that is placed at the bony cartilaginous junction.

All residual TM remnants are removed, including the annular ligament. Similarly to the case with traditional lateral onlay grafting, this technique does not allow the mucosa lined TM undersurface to be placed atop the graft material, thereby minimizing the complication of neotympanic mucosalization and 'wet ear'. Unlike traditional lateral onlay, the tympanic annulus is not preserved. The tedious removal of the keratinized epithelium from its surface is bypassed, and the inherent predisposition to intratympanic postoperative cholesteatoma formation is avoided. In many instances, the additional exposure that is provided by minimally widening the annular ring into the hypotympanum and posterior mesotympanum without regard for annulus preservation is useful for complete exenteration of disease. Additional widenings can be reconstructed easily with tragal or conchal cartilage if need be.

A generous canalplasty is mandatory (Fig. 9, cross-hatched area). The intent of the canalplasty is not only to provide maximum visibility for transcanal middle ear work but also to create a less acute anterior as well

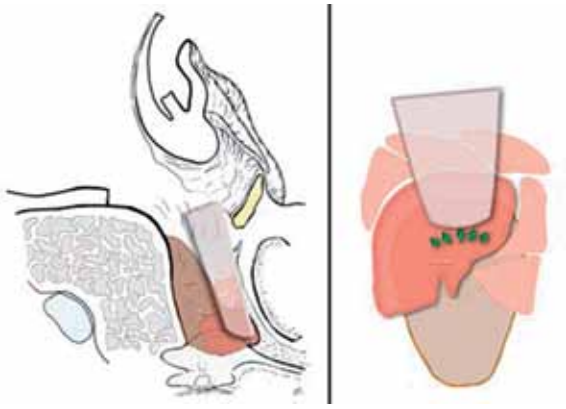

Fig. 11. Cross-sectional (A) and transcanal (B) schematic of proper placement of silicone stent

as inferior angle and to create an anterior shelf upon which to apply the rigid silicone stent during external canal packing (Fig. 9, arrow). Creating a generous inferior canalplasty eliminates the acute inferior canal-to-neotympanic angle, thereby maximizing the surface area of the neotympanum and theoretically improving the neotympanum to footplate area ratio-dependent sound pressure amplifier.

Grafting is performed with a large teardrop-shaped graft of either temporalis fascia or alternative suitably sized material, long enough to drape partially onto the anterior canal wall as well as completely up the posterior canal wall (Fig. 10 A, B).

The middle ear is filled with small cut squares of gelfilm to maintain a middle ear space. Primary ossiculoplasty is performed at this point in appropriate cases by using conventional techniques.

The free anterior wall skin graft is placed as in figure 10 C so that it bridges both the canal wall bone

and covers the exposed malleus handle. Split-thickness skin grafting from the postauricular wound edge is used to resurface any accessible exposed bone of the external auditory canal (Fig. 10 C).

Once the free-skin and split-thickness skin grafts are in position, the anterior silicone stent is placed. Care is taken to secure the stent against the shelf created during the canalplasty (Fig. 11).

The Koerner's flap is replaced onto the posterior graft, and the external auditory canal is packed with antibiotic-soaked cotton gauze strips introduced along the anterior silicone stent to act as a rigid unit during the healing period and thereby minimize the risk of graft lateralization.

An appropriate cephalosporin or quinolone antibiotic (in cases of cholesteatoma) is given for 14 days postoperatively.

Three weeks postoperatively, the external auditory canal packing is removed, with the exception of the silicone stent. The wound is repacked with 1/8-in. cotton gauze strips coated with a mixture of antibiotic, antifungal and corticosteroid preparations. The pack is left in place for another 3 weeks, after which time all material, including the silicone stent, is removed and the ear is examined. If epithelialization is near complete, Gelfoam is focally applied. Additional cotton gauze packing is placed at this point only if required, and an additional 3 weeks is allowed to pass. In younger patients or rare instances of local intolerance to the packing materials, the interval of exchange may be shortened to 2 weeks or even weekly.

Otic drops are administered throughout the postoperative course, beginning after the mastoid dressing is removed and continuing until complete epithelialization has occurred and all packing is removed.

Advantages/Disadvantages

The Zone Based Techniques are based on the principle of advancing tympanomeatal flaps. They are largely underlay techniques and therefore may result in neotympanic epithelialization. It is important therefore to trim as much excess inflammatory tissue and mucosa from the undersurface of the flaps prior to placement of the graft. We have found this process to be facilitated by the use of handheld CO_2 lasers, which have recently been introduced with spot sizes in the order of 250–300 microns. The safety profile of these instruments and their theoretical advantages has been carefully documented [7].

Because the rotational flaps used in these techniques moves skin off of the ear canal, there is the potential disadvantage of delayed epithelialization of the harvest site. This however is counterbalanced by the advantages gained by moving these hardy flaps over to expedite formation of a stable neotymanum. In rare cases, where there is protracted exposed bone, it can usually be remedied by the use of local split thickness skin grafting. This may performed as a distinct procedure or done at the time of second stage explorations or ossiculoplasties in cases of planned staging.

The use of autologous temporalis fascia as a grafting material is well documented in the literature for perforations of various extent [8–11]. Successful closure was documented by Kartush et al in 120 patients at 6 months' follow-up who were undergoing an over-under technique; however, 12 patients developed late TM perforations. Singh et al showed similar results (93.3% closure rate) using an overlay and underlay technique in 60 patients with dry subtotal perforations secondary to chronic suppurative otitis media. However, Khan et al. reported a TM closure rate of 84% at 5-year follow-up in 69 patients who underwent an underlay tympanoplasty with temporalis fascia. Similarly, Berger et al showed a success rate of only 52.8% in revision myringoplasty patients. Of the failures, 39.4% were caused by complete no-take of the graft material. In general, success rates of more than 90% can be achieved regardless of surgical technique employed [12]. Rates of closure have been similar with dermal allografts. Fayad reported an 87.5% closure rate [13].

TTMR differs from traditional lateral only in that the entire annular ligament is removed, along with any unusable TM remnants. It is characterized by an extreme lateral anterior free graft harvest incision, silicone stenting, and split-thickness skin grafting. The 92% overall closure rate obtained with TTMR by Fishman [5] is comparable to those reported in routine cases using traditional techniques. Of those patients grafted with available temporalis fascia, 97% had successful closure. In this study, the overall postoperative air-bone gap was less than or equal to 20 dB in 89% of all patients undergoing TTMR. Sixty-six percent of patients achieved an air-bone gap of less than or equal to 15 dB. Fifty-one percent had an ultimate air-bone gap of 10 dB or less. Considering that TTMR is designed to address those severe cases without available residual TM, this is a highly favorable outcome.

The primary advantage of the TTMR technique is that is does not require any residual fibrous tympanic membrane or annulus. The technique can therefore be utilized in the most severe cases where no usable tympanic membrane remnant is present. This makes it particularly useful in the treatment of benign temporal bone neoplasms or revision chronic ear surgery with mucosaliziation extending lateral to the tympanic annulus, medial stenosis as well as post radiation changes. With removal of the annular ligament, access to the hypotympanum can be liberally extended by freely drilling down the bony annulus. The bony defect can be easily reconstructed with cartilage grafts taken from either the tragus or the conchal bowl. Because

all the skin of the ear canal is removed and the canal liberally widened, there is ample room through which to work, making the technique ideal for extensive cholesteatomas and benign neoplasms of the middle ear and temporal bone. With strict adherence to technical details, there should be no implantation of mucosal cells lateral to the graft, virtually eliminating the issue of postoperative mucosalization.

Disadvantages center primarily on the technique sensitive nature of the procedure and duration of stenting. While children may heal within approximately 4 weeks time, the typical expected time to complete healing may range from 6–9 weeks in adults. The silicone stent is left in place for up to one month in children and 4–6 weeks in adults for optimum healing. During this period of time, the patient requires changing of the external gauze packing every 2–3 weeks. The packing is well tolerated in most patients who are still locally insensate during this period of healing. The postoperative care requirements may also be a limitation for patients travelling from long distances. In these cases, alternative methods may be utilized, or arrangements can be made with suitably trained local physicians.

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