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With a thankful heart for their love and nurturing, this book is dedicated to my parents, the late Mr. and Mrs. Lee Cheng Tin.

K. J. Lee

For all their years of love and support through this journey in medicine so far away from home, I dedicate this book to my parents.

Elizabeth H. Toh
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Foreword

A notebook is intended for items of importance stated briefly or written down for review to aid the memory. K. J. Lee and Elizabeth H. Toh have compiled a remarkably useful tool for the busy surgeon. This surgical notebook has a step-by-step approach to preoperative evaluation, operative care, and postoperative considerations for patients undergoing a wide variety of otolaryngologic procedures.

*Otolaryngology: A Surgical Notebook* was designed with the busy resident in mind. It clearly would be a great addition to the library of every medical student seriously interested in otolaryngologic care. The *Notebook* is authored by a wonderful cast of otolaryngologists of international renown. The writing is clear and to the point. The most important considerations are bulleted to facilitate easy reference and review. When appropriate, illustrations are supplied. I expect that you will find *Otolaryngology: A Surgical Notebook* a welcome addition to your library.

*Jonas T. Johnson, M.D.*
Preface

Talking with residents and fellows, we are reminded that the only certainty during those years of training was that time was a valuable commodity when there was so much to be done and so much to be learned in so few years. This surgical notebook is not meant to be a complete review of otolaryngology, nor a complete surgical manual. The intent of this book is to review essential steps in the most commonly encountered procedures performed by otolaryngologists and to provide practical pointers and pitfalls that one may encounter preoperatively, intraoperatively, and postoperatively. To a large extent, this work reflects the collective experiential knowledge of its contributors gained through their own surgical successes and failures. We hope that this guide will serve to rapidly review critical steps in otolaryngologic surgery and further consolidate the surgical experience gained in the operating room.

K. J. Lee conceived of this book; Elizabeth H. Toh, however, almost single-handedly recruited contributors, edited their work, and compiled the chapters. This book would not have been finished without the relentless efforts of Elizabeth H. Toh; the publisher and K. J. Lee salute her.

K. J. Lee, M.D.
Elizabeth H. Toh, M.D.
Acknowledgments

I am much indebted to Dr. Ashley Wackym and all the physicians at the House Ear Clinic, including the late Drs. Howard House and James Sheehy, with whom I have had the privilege of spending some very stimulating and productive years. Their invaluable wisdom, patient guidance, and unfailing support have enabled me to build a firm foundation in otology and neurotology, on which I continue to build with my own experience.

I am also grateful to my colleague and friend Dr. Barry Hirsch, who has generously shared his experience and expertise with me, and who has enabled me to continue to mature in my practice. His friendship and support are deeply appreciated.

I would also like to thank my coeditor, Dr. K. J. Lee, for conceiving, supporting, and mentoring this work. Through this project, I have gained not only a professional and personal role model, but a teacher and a friend. Special thanks also to Mary Lee McAndrew for her assistance in putting this manuscript together, to our publisher Thieme Medical Publishers, Inc., and to our many contributing colleagues for sharing and supporting our vision.

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1

Septoplasty, Septal Reconstruction, Surgery of the Septum and Turbinates

K. J. Lee

◆ Septum Surgery

The goal of correcting a deviated septum is to eliminate the obstructing components of the cartilaginous and bony septum while preserving support of the nasal architecture and avoiding a septal perforation.

◆ In general, two types of incisions can be utilized:

○ Killian incision  Used for patients whose cartilaginous septal deviation does not involve the caudal aspect of the septum. The advantage of using this incision is that no septal-columellar sutures are needed, thus avoiding possible postoperative suture irritation at the columellar site.

○ Hemi-transfixion incision or Cottle incision  Used for patients whose cartilaginous septal deviation includes the caudal aspect. The caudal septum deviates into one nostril or the other. This incision allows the surgeon to correct the deviated “caudal strut” and anchor it in the midline with two or three 3–0 chromic mattress sutures. The caudal strut cannot be sacrificed; the lack of a caudal strut will lead to columellar retraction and lack of tip support.

◆ In developing the mucoperichondrial and mucoperiosteal tunnels bilaterally, great care should be exercised to avoid through-and-through septal mucosal perforation. The use of the Freer septum knife (Storz N-2252, nicknamed “D knife” because it is shaped like the letter D) is very helpful.

◆ Sometimes it is easier to develop the mucoperichondrial or mucoperiosteal flaps after a piece of cartilaginous cartilage is removed. Great care should be exercised to leave a dorsal strut to avoid saddle deformity, and to leave a caudal strut to avoid columellar retraction.
A deviated cartilaginous septum dislocated off the vomerian ridge can be missed. Hence, careful inspection of that area should be performed routinely.

Bony spurs need to be isolated from periosteum bilaterally and removed with Jansen Middleton septum forceps or with a 4 mm chisel. A wider chisel should be avoided. The chisel should be directed parallel to the vomer or slightly superiorly, away from the palate, so as not to injure the palate.

For the comfort of the patient, some surgeons opt not to insert postoperative nasal packing. The author believes that a 4-day nasal pack bilaterally helps to stabilize the corrected deviated septum along with the mucoperiosteal and mucoperiosteal flaps, thus preventing subsequent “redeviation” of the septum. When placing the packing, use an “accordion” approach to avoid dislodging the packing into the nasopharynx.

Before the packing (petroleum jelly strip packing impregnated with bacitracin ointment) is placed, a strip of Telfa® (1 x 3 inches) is placed alongside the septum on each side.

# Turbinate Surgery

The goal of turbinate surgery is to reduce the “bulk” obstructing the nasal air passages. Total inferior turbinectomy is to be avoided because it can lead to rhinitis sicca. Different techniques are available. With polypoid degeneration of the middle turbinates, partial or subtotal middle turbinectomy is recommended. Care should be exercised to get good control of intraoperative and postoperative bleeding.

Cauterizing the turbinate edges to reduce bulk limits the likelihood of the turbinate becoming hypertrophied again. This is a common safe technique. Bovie cautery is readily available, and the use of it does not necessarily increase cost, surgical risk, or operating time. Ascertain that the patient is properly grounded. Postoperative crusting can be handled with water or saline drops and douches. In the author’s experience, the crusting does not last more than 7 to 10 days.

A variation of this is to insert a cautery needle into the inferior turbinate. The author has not noticed any advantage using the needle technique.

The use of laser accomplishes the same effect—tissue destruction by heat. Some claim that the laser produces less crusting; this has not been noticed by the author. Laser equipment is expensive, and the use of this modality introduces an element of fire hazard.

The use of radiofrequency is another option. It is the author’s analysis that radiofrequency has no advantage over cautery yet increases the cost of the procedure.

Cryosurgical desiccation is another modality. In the author’s experience, it gives rise to a great deal of crusting for 2 to 3 weeks. The use of cryosurgery also increases the cost of the procedure.

Surgical (knife or scissor) excision of part of the inferior turbinates gives rise to significant bleeding. Submucosal dissection and then partial excision is preferred to “just” removing part of the cartilage/bone and mucosa.
In the mid-1980s, sinus surgery shifted to a more physiological basis as attention was directed to the osteomeatal complex through the introduction and popularization of functional endoscopic sinus surgery (FESS). Since that time, FESS has emerged as the preferred surgical modality for the treatment of chronic rhinosinusitis (CRS) that has proven refractory to aggressive medical treatment. Numerous technological advances over the past 2 decades have served to facilitate the implementation of FESS principles, but the emphasis upon restoration of mucociliary clearance and preservation of sinus mucosa has only grown stronger.

This chapter will focus on the surgical management of CRS after medical treatment has failed. Because FESS alone will not provide optimal results, special consideration will be given to perioperative management, which optimizes the surgical results.

Over the past 10 to 15 years, endoscopic techniques have been developed for septoplasty, cerebrospinal fluid (CSF) leak repair, orbital decompression, optic nerve decompression, dacryocystorhinostomy, hypophysectomy, and tumor resection. Discussion of the procedures is beyond the scope of this chapter.

◆ Preoperative Care and Decision Making

Chronic Rhinosinusitis Diagnosis

Although complaints of nasal and sinus symptoms rank among the most common health complaints, considerable controversy persists about the definition of chronic rhinosinusitis. In its most general sense, CRS represents a long-standing inflammatory process involving the contiguous mucous membranes of the nose and paranasal sinuses. Rather than a disease with a single pathophysiology, CRS is a syndrome of various specific diseases, including but not limited to sinonasal polyposis, sinus
mucocele, chronic suppurative bacterial infection, eosinophilic rhinosinusitis, aspirin (ASA) triad (also known as Sampter's triad), and allergic fungal rhinosinusitis (AFRS). From a practical standpoint, confirmation of a specific pathophysiology is problematic; fortunately, an operational approach for CRS diagnosis may be used. This strategy for CRS diagnosis relies on the major and minor diagnostic factors summarized in the 2003 Sinus and Allergy Health Partnership consensus statement (Table 2–1).3 The presence of two major factors for more than 12 weeks constitutes a history that is strongly supportive of the clinical diagnosis of CRS. Two minor factors and a single major factor for an equivalent time period provides similar evidence for CRS. It must be remembered that clinical symptoms alone may be a poor marker of CRS; therefore, CRS diagnosis in patients with a strong clinical history must be confirmed by the objective means of nasal endoscopy and/or sinus computed tomography (CT).

Nasal endoscopy is an important tool for CRS diagnosis because it provides visualization that simple anterior rhinoscopy cannot duplicate. Relatively subtle changes, such as polypoid mucosal changes, mucosal edema, and purulent drainage, may be easily appreciated during routine office-based endoscopic examinations. Furthermore, nasal endoscopy provides access for direct sampling of purulent nasal secretions for culture. Admittedly, endoscopic visualization may be limited in some patients with unfavorable nasal anatomy, even with the application of topical decongestants and anesthetics. In addition, the endoscopic examination may be relatively normal in patients with quite extensive paranasal sinus opacification on sinus CT. Therefore, one must not overly rely upon nasal endoscopy for CRS diagnosis.

Sinus CT is certainly a sensitive method for assessing paranasal sinus aeration; however, even relatively minor upper respiratory illnesses may be associated with extensive but reversible paranasal sinus opacification. For this reason, the clinician must interpret sinus CTs in a framework defined by the clinical history of the patient at the time of CT scan acquisition.

<table>
<thead>
<tr>
<th>Major factors</th>
<th>Minor factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facial pain/pressure*</td>
<td>Headache</td>
</tr>
<tr>
<td>Nasal obstruction/blockage</td>
<td>Fever (all nonacute)</td>
</tr>
<tr>
<td>Nasal discharge/purulence/discoled postnasal discharge</td>
<td>Halitosis</td>
</tr>
<tr>
<td>Hyposmia/anosmia</td>
<td>Dental pain</td>
</tr>
<tr>
<td>Purulence in the nasal cavity on examination</td>
<td>Cough</td>
</tr>
<tr>
<td>Purulence in the nasal cavity on examination</td>
<td>Ear pain/pressure/fullness</td>
</tr>
</tbody>
</table>


* Facial pain/pressure alone does not constitute a suggestive history for rhinosinusitis in the absence of another major nasal symptom or sign.

** Fever in acute rhinosinusitis alone does not constitute a strongly suggestive history for rhinosinusitis in the absence of another major nasal symptom or sign.
Recurrent acute rhinosinusitis is characterized by frequent episodes (more than four to six episodes per year in adults) of purulent acute rhinosinusitis, with symptomatic resolution between episodes. Because symptoms are a poor marker of inflammatory paranasal sinus disease, confirmation of this diagnosis includes nasal endoscopy and/or sinus CT during an active episode. Recurrent acute rhinosinusitis may mimic frequent episodes of viral rhinitis. In general, viral rhinitis symptoms are much less severe and more self-limiting (Table 2–2). Most episodes of acute rhinosinusitis are preceded by viral rhinitis, and most attacks (>95%) of viral rhinitis resolve without specific intervention within 7 to 10 days of onset. Persistent or worsening symptoms beyond 10 to 14 days suggest the presence of an acute bacterial sinus infection.

Some patients with CRS may experience acute exacerbations that are characterized by a symptomatic flare-up of their baseline symptoms. During an acute exacerbation of chronic rhinosinusitis, a patient’s characteristic symptoms grow acutely worse, but with appropriate treatment, symptoms return to baseline.

**Chronic Rhinosinusitis Treatment**

The primary management of CRS is medical; surgical intervention is reserved for those patients in whom this medical treatment has failed. Almost all patients who undergo sinus surgery will also require long-term medical management of varying intensity. Therefore, rhinologic surgeons must be familiar with important concepts in CRS medical management:

- CRS medical therapy focuses on the two underlying themes in CRS pathophysiology, which is felt to represent an underlying inflammatory process and an infectious process.
- Because CRS is a long-standing illness, aggressive treatment is often prolonged, and some patients require treatment indefinitely.
- The microbiology of CRS differs from acute rhinosinusitis, in which the primary organisms are *Streptococcus pneumoniae, Haemophilus influenzae,* and *Moraxella catarrhalis.* In particular, some studies seem to indicate that anaerobes play a much larger role in CRS. The primary pathogens for CRS include coagulase-negative staphylococcal species, *Staphylococcus aureus,* *Streptococcus* species *Pseudomonas aeruginosa,* and enteric gram-negative bacteria, as well as the more common pathogens associated with acute rhinosinusitis.
Empiric antimicrobial therapy should provide coverage for the likely organisms. Amoxicillin/clavulanate, respiratory quinolones (levofloxacin, moxifloxacin, temafloxacin, etc.), second-generation cephalosporins, and macrolides (clarithromycin, rather than azithromycin and erythromycin) all may be used for empiric treatment. If empiric treatment fails, switching to another antimicrobial class should be considered.

Adequate antimicrobial treatment should last for at least 4 weeks and possibly longer.

Ideally, antibiotics selection is based on cultures obtained under endoscopic visualization.

Nasal endoscopy provides a means for both establishing the diagnosis of CRS and gauging its response to therapy.

Important adjuvant medications in CRS treatment include mucolytics (guaifenesin 600–1200 mg po bid) and topical nasal steroids (budesonide, flunisolide, fluticasone, mometasone, and triamcinolone). Often topical nasal steroids are used at doses 2 or 3 times the standard dosing for allergic rhinitis.

Concomitant inhalant allergies require appropriate medications, including systemic antihistamines (cetirizine, desloratadine, fexofenadine, etc.) and topical antihistamines (azelastine). Older, first-generation systemic antihistamines may have a significant drying effect on the sinonasal lining and probably should be avoided.

Many CRS patients also have asthma. Because of the relationship between CRS and asthma, comprehensive CRS treatment includes coordination with the patient’s other physicians who are actively managing the reactive lower airway disease.

Many patients also benefit from the administration of systemic corticosteroids. In particular, patients with sinonasal polyposis and/or ASA triad are candidates for systemic steroid treatment. Short bursts of steroids (i.e., methylprednisolone dose pack) may be used, but more severe sinonasal inflammation will require longer treatment courses (i.e., prednisone 40 mg po daily × 3 days, then 30 mg po daily × 3 days, then 20 mg po daily × 3 days, then 10 mg daily × 3–6 weeks, with a final taper adjusted based on response, side effects, etc.) Unfortunately, systemic corticosteroids carry significant morbidity (including weight gain, mood changes/swings, diabetes, hypertension, osteopenia/osteoporosis, glaucoma, cataracts, rare avascular necrosis of a major joint, etc.); patients must be counseled about these issues. Furthermore, physicians should perform a risk assessment before commencing systemic steroids. In particular, ophthalmological evaluations for glaucoma and cataracts as well as bone densitometry should be considered.

Indications for functional endoscopic sinus surgery include the following:

- **Symptomatic, refractory CRS** The diagnosis should be confirmed by CT obtained after aggressive medical treatment (administered during a 6–8 week period).
- **Recurrent acute rhinosinusitis** This diagnosis must be confirmed by an abnormal CT or nasal endoscopic examination performed approximately 7 to 10 days after
the onset of symptoms. The minimal frequency should be at least four to six episodes per year.

- **Frontal sinus and/or sphenoid mucocele**  Complete opacification of the frontal or sphenoid sinus, especially when associated with bony remodeling and expansion of the sinus, suggests the presence of a mucocele. If medical treatment does not produce at least partial aeration, endoscopic marsupialization is warranted to prevent delayed complications even in the absence of symptoms. The presence of bony erosion, even if such erosion brings sinus mucosa into contact with the dura, requires a functional, endoscopic approach.7

- **Acute suppurative complications of rhinosinusitis**  In these instances of secondary orbital infection (subperiosteal abscess, orbital cellulitis) and intracranial complications (meningitis, extradural abscess, etc.), the functional endoscopic technique may be substituted for the traditional, nonendoscopic techniques. Of course, the management of these complications requires coordination of care with neurosurgery, ophthalmology, infectious disease, neuroradiology and other allied disciplines.

- **Noninvasive fungal sinusitis**  Both mycetoma and AFRS require operative intervention for confirmation of diagnosis and treatment. For mycetoma, such a procedure is likely to be curative; for AFRS, a nondestructive, functional approach is warranted because multiple procedures over many years may be necessary.

- **Invasive fungal sinusitis**  Initial surgical management of invasive fungal rhinosinusitis may rely on FESS principles; however, the surgical objective of complete debridement will likely require nonfunctional tissue resection, which still can be performed under endoscopic visualization.

## Preoperative Considerations

In general, FESS is elective surgery. Therefore, before committing to surgery, the surgeon and patient must explore these questions:

- Does the patient report symptoms that are consistent with the objective findings noted on his or her sinus CT and during nasal endoscopy?
- Has the patient received adequate medical treatment?
- Does the patient indicate that his or her persistent symptoms are having an adverse impact on his or her quality of life?
- Has the patient’s general medical condition been optimized for the procedure and postoperative recovery?
- Does the patient understand the likely clinical course, need for postoperative care, risks of the procedure, and other issues?

If the answer to any of these questions is no, then the decision for elective surgery should be postponed. Informed consent for FESS should include a frank discussion of its risks, benefits, and alternatives. The risks of any sinonasal procedure include scarring, recurrence, septal injury (if septal work is planned), bleeding, infection, orbital injury, intracranial injury, anesthesia, and death. Although major complications occur rarely, the patient should understand that FESS is not a minor procedure. Similarly, the rhinologic
surgeon should be prepared for the management of both minor and catastrophic complications.

The preoperative CT scan serves as the road map for all FESS procedures. At a minimum, a 3 mm coronal sinus CT with bone windows must be available. Axial images are also helpful, especially if sphenoidotomy is planned. Since the mid-1990s, computer-aided surgery (CAS), also known as image-guided surgery (IGS), has become a de facto standard at many leading rhinology centers. Because the CT slice thickness sets the best possible surgical navigation accuracy, a 1 mm axial CT is desirable. The rhinologic surgeon who incorporates CAS into FESS must realize that greater slice thicknesses limit surgical navigation accuracy and thereby compromise the advantages offered by this technology.

Indications for the use of CAS during sinus surgery include:

- Revision sinus surgery
- Frontal recess surgery
- Posterior ethmoid and sphenoid surgery
- Sinonasal polyposis
- Advanced endoscopic applications (CSF leak repair, orbital decompression, optic nerve decompression, tumor resection)
- Congenital/traumatic/postsurgical craniomaxillofacial anomalies

◆ Operative Technique

The goal of all FESS procedures is the restoration of mucociliary clearance, not the removal of so-called diseased tissue. The emphasis is on establishing sinus aeration in such a way that the normal mechanisms of sinus function can reestablish themselves in the postoperative procedure. As such, mucosal preservation is paramount.

Operating Room Setup

Every surgeon devises an operating room (OR) setup that is conducive to his or her work. Regardless of the specifics, the equipment must be arranged so that it reflects the delicate nature of this work. Considerations in the OR setup include the following:

- Although most surgeons now use a video camera and display for visualization, a few rhinologists still prefer to look through the eyepiece of the nasal telescope. Admittedly, the image provided by the eyepiece is bright; however, it is quite small. Contemporary three-chip cameras provide nearly equivalent image quality as well as image magnification. Because the video display can be set at eye level, the surgeon who uses the camera is more comfortable and less likely to fatigue during time-consuming, delicate procedures. He or she is also less likely to develop back and neck injuries during his or her career.
- The ideal position for the surgeon is probably sitting, so that the potential for fatigue is minimized. A comfortable surgical stool is required, and padded armrests serve to further reduce surgeon’s fatigue.
Close coordination with anesthesia is important. If the patient is awake but sedated, the patient's airway must be monitored. If the patient is intubated for general anesthesia, then the endotracheal tube and anesthesia circuit must be placed in such a way that they do not interfere with access to the nose. Similarly, electrocardiogram (EKG) leads and other wires, as well as intravenous (IV) lines, must be secured so that they do not block the surgeon.

The scrub technician should be familiar with the instruments. It is certainly in the surgeon's best interest to take the extra time to educate the scrub technician about the instruments. Color-coded labels for instruments can be helpful.

Anesthesia Considerations

FESS procedures may be performed under general anesthesia or local anesthesia with intravenous sedation. For the latter strategy, the anesthetist must be adept at maintaining an adequate level of sedation. General anesthesia is required for more complex FESS procedures of greater duration.

CT Scan Considerations

The CT scan is the road map for all FESS procedures. Adequate CT scan images (discussed above) must be available at the time of surgery. During preoperative planning, the surgeon should construct a mental three-dimensional model of the patient's anatomy. The model should include anatomical features that may increase the risk of complications; in this regard, bony dehiscences, the skull base configuration, and prominent anterior ethmoid neurovascular bundles, among other features, should be noted.

Extent of Surgery

For patients with less than pansinusitis, the extent of the surgery must be considered. Of course, complete endoscopic sphenoidotomy is not warranted for patients with mild anterior ethmoid and maxillary sinusitis. As a general rule, the surgery should address those areas that are opacified on the preoperative CT scan. In particular, adjacent apparently normal ethmoid cells should be opened to ensure complete surgery during partial endoscopic ethmoidectomy. During a primary FESS procedure, formal frontal recess dissection is not absolutely necessary for mild frontal recess mucoperiosteal thickening, although formal endoscopic frontal sinosotomy should be considered. At the conclusion of partial ethmoidectomy procedures, the operative field should be carefully inspected. Collapsed residual ethmoid cells, which may predispose the patient to delayed iatrogenic mucocele formation, should be addressed.

Nasal Telescope Handling

Nasal telescopes are delicate optical devices. Inappropriate instrument handling will compromise image quality. Periodic servicing and replacement of all nasal telescopes are recommended.
Although the telescopes provide adequate visualization, the view is not analogous to looking through a windowpane. The endoscopic image has an intrinsic symmetrical spherical aberration (like a fish-eye camera lens). The angled 30, 45, and 70 degree lenses further exacerbate this potential for visual disorientation. In order to minimize this perceptual confusion, it is important to keep the image appropriately oriented, especially if one uses a camera and video monitor system.

Several available irrigation systems for cleansing the scope lens offer the advantage of keeping the view clear in a bloody field. Unfortunately, the bulk of the scope sheaths for these systems cause additional mucosal trauma, which only worsens the problem of a bloody field. A better alternative is to minimize inadvertent trauma to the nasal mucosa. Application of antifog solution to the tip of the scope is necessary to prevent condensation or fogging of the scope lens.

**Preparation of the Operative Field**

Before commencing surgery, the nasal mucosa must be adequately decongested. Although some surgeons recommend topical cocaine, topical 0.05% oxymetazoline on cotton packing provides an excellent decongestant effect and avoids the potential complications associated with topical cocaine. If the procedure is performed under intravenous sedation, topical anesthetic (4% lidocaine or topical cocaine, which also has anesthetic effects) must be applied.

In all cases, local anesthetic (1% lidocaine with 1:100,000 epinephrine) should be infiltrated into the sphenopalatine region and uncinate process under endoscopic visualization. A bent 23-gauge spinal needle may be used for the transnasal sphenopalatine injection, and a bent 2 inch, 25-gauge needle should be used for the uncinate process injection. If transnasal access for the sphenopalatine block cannot be achieved, a transpalatal sphenopalatine block may be used. For this injection, local anesthetic is injected through the greater palatine foramen with a 25-gauge needle. Care should be taken not to pass the needle tip more than 15 to 20 mm through the foramen to avoid violation of the inferior orbital fissure. Of course, visible nasal polyps may also be infiltrated with local anesthetic.

Before any local infiltration, gentle aspiration should be performed to avert inadvertent direct intravascular injection. Waiting several minutes after application maximizes the vasoconstrictive effect of the epinephrine.

**Instrumentation**

Today’s instruments for sinus surgery represent significant improvements over traditional sinus surgery instruments:

◆ Almost all contemporary sinus instruments are much smaller than their traditional forebears. As such, they are more appropriate for working in the narrow passages of the paranasal sinuses. Older instruments are simply too big.

◆ Through-cutting forceps facilitate the precise removal of tissue and avoid inadvertent mucosal stripping. Such instruments are required for all FESS procedures.

◆ Powered instrumentation (also known as the “shaver” or “microdebrider”) permits the rapid, efficient, and precise removal of soft tissue and even bone. These devices are best suited for sinonasal polyposis, but they also may be used in other cases.
Care must be taken to avoid overly aggressive mucosal loss, especially in narrow regions (e.g., the frontal recess). More recent iterations of this technology are more powerful and probably carry a greater risk of skull base and orbital complications.

- Specific frontal recess instruments (frontal recess curets, grasping giraffe forceps, through-cutting giraffe forceps, and curved suctions) are essential for all frontal recess work. They have the reach necessary to ensure precise dissection in this region.

Bleeding

The best management strategy for bleeding is prevention. Inadvertent trauma to the septum and turbinates simply produces bleeding that obscures adequate visualization. Gentle, atraumatic technique is essential. In addition, surgeons must allow adequate time for the vasoconstrictive effects of the topical decongestant and infiltrated local anesthetic.

If the amount of oozing is significant, the sinus cavities may be backed with pledgets soaked with 0.05% oxymetazoline for a few minutes. Although a suction monopolar cautery may be appropriate for the inferior turbinates, monopolar cautery should not be used within the sinus cavities, in the sphenopalatine region, and along the sphenoid face, because of the risk of direct injury to neighboring critical structures. Bipolar cautery is strongly encouraged when discrete bleeding points are present. Some bipolar cautery devices offer concomitant suction, which can be helpful.

During the procedure, care must be taken in the regions of the sphenopalatine artery, anterior ethmoidal artery, and posterior ethmoidal artery to avoid direct injury to these vessels. Because the septal branches of the sphenopalatine artery cross the inferior part of the sphenoid face, some increased bleeding during sphenoidotomy may be anticipated.

Frontal recess dissection should be performed last so that bleeding from this region does not obscure the rest of the operative field.

Inferior Turbinate Management

In general, inferior turbinate reduction should not be a part of routine FESS procedures because apparent inferior turbinate hypertrophy probably reflects the diffuse inflammatory state of the sinonasal mucosa, rather than a problem with the inferior turbinates themselves.

Numerous procedures for inferior turbinate reduction have been proposed. Complete or even partial amputation of the inferior turbinates should not be performed for benign, inflammatory diseases. Submucosal inferior turbinate reduction, which does not disrupt the mucosal surface of the inferior turbinate and still preserves its three-dimensional shape, is the preferred procedure. Powered instrumentation greatly facilitates submucosal inferior turbinate reduction:

- The procedure should be performed under endoscopic visualization in the operating room.
- Local anesthetic should be infiltrated directly into the inferior turbinate.
A vertical incision at the anterior edge of the inferior turbinate is performed.

Next, a Cottle or Freer elevator is used to elevate the mucosa from the medial surface of the inferior turbinate bone. Care is taken not to perforate this flap.

The tip of the powered instrumentation device is then introduced into the pocket. The biting surface is oriented to the inferior turbinate bone. Depending on the configuration of the powered instrumentation tip, varying amounts of bone and soft tissue can be removed. The goal is a reduction of the inferior turbinate volume with preservation of its overall shape. Perforation of the inferior turbinate mucosa should be avoided.

Nasal packing is not required; however, the placement of Silastic septal splints should be considered if septal trauma from concomitant septoplasty or other intranasal manipulations is present. The splints can be removed in the office 5 to 7 days later.

Inferior turbinate outfracture is not recommended.

Middle Turbinate Management

Middle turbinate resection is not a routine part of FESS procedures for inflammatory disease. Both total and partial middle turbinate resection may lead to middle meatal scarring and frontal recess stenosis. With appropriate care, the objectives of FESS can be achieved with complete preservation of the middle turbinate.

When a concha bullosa is present, the resultant enlargement of the middle turbinate can block access to the middle meatus. In this situation, the lateral half of the concha bullosa should be resected with complete preservation of the remaining attachments of the middle turbinate.

The key for handling the middle turbinate is gentle, atraumatic technique. If necessary, the middle turbinate may be gently retracted, but it should not be deliberately fractured. If the middle turbinate becomes destabilized or floppy during the procedure, its medial surface and the corresponding part of the septum should be deliberately abraded, and a middle meatal spacer pack should be kept in place for at least 5 to 7 days. The objective is to create adhesions that will pull the middle turbinate medially.

Septoplasty

Ideally, septoplasty will not be necessary at the time of FESS, although in practice it may be necessary to perform both procedures at the same time. If so, as much of the endoscopic work as possible should be performed before septoplasty, then the remaining endoscopic work should be completed. Septoplasty is usually performed under traditional, headlight illumination, although endoscopic visualization should be considered. Regardless, the fundamental principles of septoplasty are applicable. (Discussion of septoplasty is beyond the scope of this chapter.)

Postoperatively, patients who undergo both FESS and septoplasty tend to have more discomfort, which limits the endoscopic debridements that can be performed. Both the patient and the surgeon must understand this limitation.
Packing

Over the past century, numerous types of nasal packing have been placed at the conclusion of sinus surgery procedures. Although the large number of alternatives precludes complete discussion of each alternative, a few general comments are in order:

◆ Packing of the entire nasal cavity is uncomfortable and, in most instances, completely unnecessary. Instead, relatively light packing of the ethmoid cavity should be considered, although some surgeons now advocate the avoidance of all packing materials.

◆ The objective of the ethmoid packing is primarily to take up space so that the entire cavity does not fill with dried bloody crusts, which delay ultimate healing and can be difficult to mobilize. Secondary objectives include the enhancement of wound healing.

◆ Expandable sponges are convenient, but unless they are coated with a nonstick surface, adjacent tissues tend to adhere to them, making removal of the sponges traumatic.

◆ Over the past several years, a variety of absorbable materials derived from hyaluronic acid have been introduced. Unfortunately, they are expensive, and some data suggest that they are associated with greater scarring, although advocates of this alternative insist that they do not see this problem clinically.

◆ Although sinus mucosa does not seem to tolerate standard oxidized cellulose (Surgicel, Ethicon, Somerville, NJ) well, its fibrillar variation (Surgicel Fibrillar, Ethicon) is extremely well tolerated. This material is easy to remove postoperatively, and the underlying mucosa seems healthy after removal.

◆ If a true hemostatic effect is desired, a slurry of absorbable collagen (Helitene, Integra Life Sciences Corporation, Plainsboro, NJ) mixed with normal saline may be applied to the middle meatus.

◆ Absorbable gelatin sponge (Surgifoam, Ethicon) has excellent hemostatic properties, but its removal from deep within the sinus cavities is problematic.

Maxillary Antrostomy Considerations

Attention should be directed at the maxillary antrostomy at the beginning of FESS for two reasons. First, ethmoid work will tend to distort the landmarks necessary for maxillary antrostomy, and second, the maxillary antrostomy leads to the visualization of critical landmarks (namely, the orbital boundaries) that facilitate the ethmoid work.

Although the initial steps for endoscopic maxillary antrostomy can be performed under the visualization provided by a 0 degree telescope, a 30 degree scope provides optimal visualization, and in some cases, a 70 degree scope must be used. Complete uncinate process removal is critical. A sickle knife may be used to perform an uncinate incision, but this approach risks violating the orbit, and as a result, there is a tendency to perform an incomplete uncinate removal. Some surgeons recommend uncinate removal by the application of powered instrumentation, but this, too, may injure the orbit. A relatively simple alternative is a three-step process. First, a back-biting forceps is used to remove a strip of uncinate process inferiorly. Next, a narrow,
90 degree Blakesley forceps is used to gently grasp and then avulse the central and superior parts of the uncinate process. Finally, the posteroinferior portion of the remaining uncinate process is removed with through-cutting forceps. Regardless of the specific measures applied for uncinate process removal, it is critical that injury to the lacrimal system, which is located anterior to the maxillary ostium, be avoided. One of the most common errors in performing maxillary antrostomy is failure to visualize the maxillary ostium. Such visualization is critical if one wants to avoid posterior placement of the maxillary antrostomy. When the maxillary antrostomy is posteriorly displaced, then postoperative mucus recirculation between the natural maxillary ostium and the posterior maxillary antrostomy may result.

**Ethmoidectomy Considerations**

The initial landmarks for ethmoidectomy are the ethmoid bulla, which can be directly incised with through-cutting forceps. Then the inferior portion of the medial orbital wall should be skeletonized. Next, additional ethmoid partitions can be removed. Entry into the posterior ethmoid is through an opening created in the central segment of the basal lamella of the middle turbinate. Posterior ethmoid cells are opened so that the sphenoid face can be identified. Subsequently, the dissection should move along the skull base in a posterior to anterior direction.

◆ The through-cutting Blakesley forceps are ideally suited to performing ethmoidectomy. In addition, powered instrumentation may be used.

◆ Complete ethmoidectomy requires complete removal of bony partitions to create a relatively smooth cavity. Stripping of mucosa must be avoided.

◆ The lateral lamella of the cribiform plate is the weakest part of the skull base. Hence, trauma to the medial superior ethmoid walls may lead to direct skull base injury and CSF rhinorrhea.

**Sphenoidotomy Considerations**

Entry into the sphenoid sinus should be through the inferomedial quadrant of the sphenoid face. Routine resection of the superior turbinate is not required. Either a transethmoidal route or a transnasal route to the sphenoid face may be used. Manipulations within the lateral part of the sphenoid sinus must be avoided so that the risk of carotid artery, optic nerve, and cavernous sinus injury are minimized.

**Frontal Recess Considerations**

Successful endoscopic frontal sinusotomy requires a complete set of frontal recess instruments. If these instruments are not available, then the procedure should not be performed.

The key anatomical point is the frontal recess concept. The frontal recess is a roughly cone-shaped space with the apex of the cone at the frontal ostium. A variety of anterior ethmoid cells pneumatize into this region.11 Frontal recess cells may be grouped into three categories. The agger nasi cell and frontal cells (types 1–4) occur in the anterior frontal recess; their posterior walls are partitions within the frontal recess. The supraorbital ethmoid cells, frontal bullar cells, and suprabullar cells
pneumatize the posterior frontal recess; their anterior walls are partitions within the frontal recess. The interfrontal sinus septal cell falls into its own group; it is categorized by a pneumatization tract from the medial frontal recess into the interfrontal sinus septum. In general, the frontal ostium is located in the medial and superior part of the frontal recess. The anterior ethmoidal artery defines the posterior frontal recess boundary; unfortunately, its landmarks are inconsistent.

During endoscopic frontal sinusotomy, the dissection removes the free cell walls of the frontal recess cells. The dissection should commence in the posterior frontal recess at the anterior ethmoid roof and then proceed in a posterior to anterior direction. Manipulations in the medial frontal recess carry the risk of injury to the lateral lamella of the cribriform plate and CSF leak.

Almost all frontal recess dissection is performed with the frontal curets and grasping and through-cutting giraffe forceps. Powered instrumentation is rarely utilized. The so-called mini-trephination procedure is not necessary, although a formal endoscopic frontal sinus trephination may be needed on rare occasions. The so-called endoscopic drillout procedures are destructive to the frontal recess mucosa and should be avoided; indications for using the drill in the narrow confines of the frontal recess are sparse.

The ideal frontal recess stent has yet to be designed. Stents are never required in primary cases, but they may be employed in revision cases where removal of circumferential scar has left circumferentially denuded bone. In these rare cases, a soft, loose-fitting stent should be inserted.

Management of Intraoperative Complications

The surgeon must be prepared to manage a variety of intraoperative complications, including hemorrhage, orbital violation, and skull base injury:

◆ **Hemorrhage**  Most bleeding resolves with the measures described above. More profuse bleeding requires nasal packing for hemostasis. Catastrophic bleeding from a major vascular injury requires immediate nasal packing, followed by angiography. If necessary, transfer to a center with the appropriate resources is warranted.

◆ **Orbital violation**  Minor orbital violations that lead to the exposure of orbital fat should be managed by avoiding further injury to that region. Cauterization or other manipulation of the fat should not be performed. The globe should be inspected and palpated. When obvious intraorbital bleeding, characterized by ecchymosis, proptosis, and so on, has occurred, lateral canthotomy and inferior cantholysis should be performed immediately. If those measures do not seem to relieve the increased intraorbital pressures, the next step is medial orbital decompression, which can be completed through a Lynch incision or under endoscopic visualization. Of course, immediate ophthalmological consultation is warranted. Adjuvant measures, including high-dose corticosteroids, mannitol, and acetazolamide, should be considered. The measures to relieve increased intraorbital pressure due to the hemorrhage should be implemented quickly over the course of 15 to 30 minutes.

◆ **Skull base injury**  Throughout any sinonasal procedure, the surgeon must monitor for the presence of a CSF leak. If such a leak is identified intraoperatively, immediate
repair should be performed by the application of grafts of mucosa, fascia, and bone/cartilage to the skull base violation. Acellular dermal allograft (AlloDerm, Life Cell Corporation, Woodland, TX) may be substituted for the fascia. Ideally, the fascia and bone/cartilage layers are wedged between the skull base and dura to fashion a tight plug.

◆ Postoperative Care

Optimal surgical results depend on appropriate postoperative care. The postoperative care strategy includes the following:

◆ In the early postoperative period, endoscopic debridements provide a mechanical cleansing to the sinus cavities until the cavities have healed.
◆ Sinus packing (if placed intraoperatively) is typically removed during the first postoperative visit.
◆ Most patients should receive a 7 to 14 day course of oral antibiotics. At a minimum, these antibiotics should provide good antistaphylococcal coverage; alternatively, antibiotics may be directed against the pathogens isolated in preoperative cultures.
◆ Patients should be advised to irrigate their noses with isotonic or hypertonic saline. A piston-type syringe with a catheter tip (Toomey syringe) is recommended. These irrigations serve to further cleanse the sinus cavities.
◆ The postoperative medical strategy closely follows the medical strategy of the preoperative period. Endoscopic surveillance, coupled with patient reports of sinonasal symptoms, guide these medical treatments. Ideally, most of these treatments may be tapered and stopped, although realistically, many patients will require long-term maintenance medications (e.g., topical nasal corticosteroids).
◆ Acute exacerbations during the postoperative period require repeat endoscopic reevaluation with cultures, which then guide further antimicrobial therapy.
◆ Usually, two postoperative visits should be scheduled in the first 2 weeks after surgery. Subsequent visits should be monthly for two to four visits, then quarterly for two to four visits. Some patients may require close evaluations on a regular basis indefinitely.

References

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Image-Guided Surgery in the Paranasal Sinuses

Siow Jin Keat and Martin J. Citardi

In 1996, the International Society for Computer-Aided Surgery proposed: “The scope of computer-aided surgery (CAS) encompasses all fields within surgery, as well as biomedical imaging and instrumentation, and digital technology employed as adjunct to imaging in diagnosis, therapeutics and surgery...”. The term image-guided surgery (IGS) has been used to describe the specific CAS application of intraoperative surgical navigation.

◆ Defining Image-Guided Surgery
◆ A computer-based system to track the position of an instrument tip that is projected as a virtual point in crosshairs on to a preoperative computed tomography (CT) scan rendered in triple orthogonal projections (coronal, axial, sagittal) simultaneously.

◆ Role of Image-Guided Systems in Sinus Surgery
◆ With IGS, the preoperative CT scans in the coronal, axial, and sagittal planes are projected on a computer monitor during surgery, and the position of the instrument tip, which is tracked dynamically, is shown relative to preoperative CT scans.
◆ IGS facilitates preoperative surgical planning by providing a better CT scan “road map” as it provides three simultaneous orthogonal planes for interpretation instead of the conventional single coronal CT scan view. The surgeon may directly relate the surgical anatomy of the preoperative sinus CT with the intraoperative anatomy of the surgical field.
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◆ How Image Guidance Works

◆ The IGS computer tracks the movement of a mathematically designated virtual point in space relative to a frame of reference via electromagnetic sensors or a camera array that detects infrared light. The tip of the instrument is not directly tracked, but its constant geometric position relative to the tracking instrumentation attached to the instrument is used to project the virtual point on the computer monitor.

◆ The computer system displays both the preoperative sinus CT and the virtual point relative to the same reference frame, thus allowing the surgeon to interpret where the virtual point is in relation to the patient’s sinuses.

◆ It should be noted that this reference frame may be a rigid physical structure (as in traditional framed stereotaxy) or a virtual frame composed of fiducial points (as in most sinus surgery applications).

◆ Components of Image-Guided Systems

1. Computer workstation
2. Display system
3. Tracking system
4. Surgical instruments that can be tracked
5. Data transfer hardware
6. Integrating software

The computer workstation interprets the mathematical spatial model of tracking that is projected onto a display system (liquid crystal display [LCD] or cathode-ray tube [CRT] monitor). The tracking system feeds information of movement of surgical instruments that are tracked to the computer workstation. In most systems, the tracking system also monitors the position of the surgical field. Data transfer hardware is required to transfer the preoperative CT scans into the computer workstation in the operating room. Such hardware may be a network system connection as well as magnetic or optical disk drives. Most commonly, data transfer of preoperative CT scan image data utilizes the Digital Imaging and Communications in Medicine (DICOM) standard. Integrating software allows for manipulation of CT images (e.g., window width and level adjustments for bone and soft tissue windows). Software may also allow coloring of a specific anatomical region such as the orbit and projecting the colored orbit in the display system during intraoperative surgical navigation for better identification. On some systems, virtual endoscopy, much like virtual colonoscopy, may also be performed by software manipulation pre- and intraoperatively.

◆ Image-Guided Systems Currently Available for Sinus Surgery

Currently available IGS systems for sinus surgery include:

1. BrainLab (Heimstetten, Germany): Vector Vision and Kolibri
2. General Electric Medical Systems Navigation and Visualization (Waukesha, Wisconsin): InstaTrak and ENTrak
Differences in Tracking Systems

Electromagnetic Systems

Work by detection of movement of a sensor within an electromagnetic field

◆ **Advantage**
  - No line-of-sight problems

◆ **Disadvantage**
  - Magnetic objects (including most surgical instruments and devices) disturb the accuracy of tracking.

◆ **Present System Available**
  - General Electric Medical Systems Navigation and Visualization: InstaTrak and ENTrak

Optical Systems

Work by detection of movement of an infrared emitter or reflector by an infrared camera array

◆ **Advantages**
  - Tracking not influenced by magnetic objects
  - When system is actively tracking, tracking error is submillimetric.

◆ **Disadvantage**
  - Line-of-sight-problems (the surgeon must maintain line of sight between the camera array and infrared emitter/reflector on the surgical instrument)

◆ **Present Systems Available**
  - BrainLab (Heimstetten, Germany): Vector Vision and Kolibri
  - Medtronic Xomed (Jacksonville, Florida): LandMarX and StealthStation
  - Stryker Corporation (Kalamazoo, Michigan): Navigation System

◆ **Essential Technical Terms**

Terms Related to Preoperative Computed Tomography and Tracking

**Calibration**  Process of establishing or confirming the relationship between a tracker and the tip of an instrument.
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**Scan volume**  The virtual volume imaged by the preoperative CT scan. Each point in this volume also has a unique \(xyz\) coordinate.

**Dynamic reference frame**  A tracker attached to the patient that serves as the reference for all localizations.

**Operative field volume**  The space around the surgical site in which tracking occurs. Each point in this volume has a unique \(xyz\) coordinate.

**Tracker**  Any device that may be used to monitor a virtual point within the operating field volume.

**Terms Related to Registration**

**Fiducial points**  Corresponding reference points (each with a unique \(xyz\) coordinate) in the CT scan volume and operative field volume that are aligned for registration. In less technical jargon, reference points on the patient upon which the preoperative CT scan is superimposed.

**Registration**  Process of aligning corresponding \(xyz\) coordinate points in the operative field volume and CT scan image volume.

**Terms Related to Accuracy**

**Fiducial registration error (FRE)**  Mathematically derived value that expresses the closeness of the fit of each fiducial point to the entire registration.

**Root mean square (RMS)**  See Fiducial registration error (FRE).

**Surgical navigation error**  An estimate of the distance between the true \(xyz\) coordinate and the indicated \(xyz\) localization provided by the navigation system. Surgical navigation error is functionally equivalent to target registration error. For clinical systems, surgical navigation error may only be determined through a visual estimation by the surgeon.

**Target registration error (TRE)**  Estimate of the error between a known point in the operating field volume and the indicated localization provided by the IGS system. TRE answers the question How close to target? TRE is the technical term for surgical navigation error.

◆ Registration Protocols

**Paired Point Registration**

Bone-anchored fiducial markers are most accurate but involve putting a screw into the skull, an impractical option in routine sinus surgery. Surface fiducial markers are pasted on the patient’s skin before preoperative CT. Such fiducials may shift due to relative movement of the skin and require the CT to be done very shortly before the operation. For paired point registration without the use of markers, anatomical fiducial points such as the tragus, the medial and lateral canthus of the eye, the ala, and the columnella of the nose must be registered just prior to the start of surgery. In general, paired point registration is considered time-consuming.
Automatic Registration

Specially designed headsets contain fiducial markers and are worn during preoperative CT scanning. The same headset is then worn intraoperatively. The headset is designed so that its placement on the patient’s head is reproducible; thus the relationship between the fiducial markers and the patient’s anatomy is deemed fixed. The computer software processes the preoperative CT data and localizes the fiducial markers automatically. Automatic registration is considered fast and efficient; however, appropriate headset placement during the preoperative CT scan and during surgery is critical.

Contour-Based Registration

The surface contour of the patient’s face can be registered by applying a laser whose reflections upon the surface is collected by the overhead camera array (also known as a digitizer). Alternatively, multiple physical localizations with a tracking probe may define a contour for registration.

Comments on Registration Protocol and Tracking System

Although automatic, headset-based registration is associated with electromagnetic tracking, and paired point registration is associated with optical tracking, the specifics of registration are independent of the tracking technology. In theory, paired point registration and automatic registration may be used with optical or electromagnetic tracking; however, each commercially available IGS system relies on a single tracking technology (optical or electromagnetic) and has been optimized by its engineers for a specific registration protocol (paired point, automatic, and/or contour-based).

Obviously, laser-based registration requires an optical digitizer. Furthermore, contour-based registration may be theoretically integrated for any type of tracking technology.

Surgical Navigation Error

RMS or FRE values do not represent the accuracy of surgical navigation. TRE is the true representation of the accuracy of surgical navigation. Clinically, TRE is the surgeon’s estimate of the closeness of image-guided system–generated localizations against known anatomical landmarks (Fig. 3–1). Intraoperative visual estimates are essential for checking system accuracy and should be repeated multiple times, as Dynamic Reference Frame (DRF) may shift during surgery. Apparent TRE estimates may vary in different parts of the operating field volume. For instance, the IGS system may seem accurate in the anterior ethmoid system but much less accurate in the sphenoid. Assessing TRE at the tip of the nose or on the surface of the cheek is thus not optimal. Such assessments should occur as close to the actual surgery sites as possible.
Indications for Image-Guided Surgery

1. Frontal sinus surgery
2. Revision surgery
3. Posterior ethmoid and sphenoid surgery
4. Sinonasal polyposis
5. Advanced endoscopic applications (cerebrospinal fluid [CSF] leak repair, orbital decompression, optic nerve decompression, tumor resection)
6. Congenital/traumatic/postsurgical craniomaxillofacial anomalies

Because not all surgical centers have an IGS system, the above indications are relative to availability of IGS and the surgeon’s comfort levels in performing more complex endoscopic procedures.
Uses of Image-Guided Systems

Image-guided systems are an enabling technology and not a substitute for surgical expertise. Throughout image-guided functional endoscopic sinus surgery (FESS) procedures, the principles of mucosal preservation and mucociliary clearance should be adhered to strictly.

Preoperative Planning

Simultaneous viewing of a single point in triple orthogonal projections (i.e., coronal, axial, and sagittal views) allows preoperative interpretation not achievable by viewing conventional coronal CT sections alone. For example, in endoscopic frontal sinusotomy, the sagittal view on CT facilitates surgical planning for the resection of the posterior leaf of an anteriorly based frontal recess cell (e.g., an agger nasi cell) and/or the anterior leaf of a posteriorly based frontal recess cell (e.g., the suprabullar cell).

Intraoperative Surgical Navigation

Although it is possible to track surgical instruments (curets and even microdebriders) continuously during surgery, this is seldom necessary in real surgical practice. IGS is certainly useful in important anatomical regions, such as the frontal recess, or when important anatomical landmarks are absent, such as in revision cases. It is also useful in confirming the position of the following:

- Skull base
- Anterior ethmoid artery
- Nasolacrimal duct during uncinectomy
- Site of transethmoid entry into the sphenoid sinus
- Optic nerve in a sphenoethmoid cell

In endoscopic surgery outside the paranasal sinuses, it is especially useful in confirming the position and thus avoiding injury to the following:

- Carotid artery
- Basilar artery
- Brainstem in skull base surgery (Fig. 3–2)

Image-Guided Surgical Technique (Fig. 3–3)

A CT scan is completed with the specific scan protocol required by the system. Ideally, the CT slice thickness is as thin as possible. For headset-based registration, the headset must be placed on the patient before scanning. Data from this CT scan is transferred to the IGS computer workstation via the computer network or disk. The surgeon reviews the CT scan preoperatively.

After induction of anesthesia, registration is performed in accordance with the protocol required by the IGS system. A visual estimate of surgical navigation accuracy
is performed. Some systems require the designation of a so-called verification point for this purpose.

Surgical navigation accuracy (also known as TRE) must be monitored throughout the procedure. Verify to a known anatomical landmark as mentioned below whenever the IGS is to be used to confirm an uncertain anatomical position. Appropriate anatomical landmarks for assessing TRE include:

- Anterior aspect of the nasal septum
- Anteroinferior aspect of the middle turbinate
- Posterior aspect of the nasal septum

Figure 3–2 Image guidance beyond the paranasal sinus. This patient has a chondrosarcoma involving the clivus. An opening has been made through the clivus. The tumor has been partially removed. The virtual point is shown on the axial and sagittal aspect of a preoperative magnetic resonance imaging (MRI) scan to be beyond the posterior limit of the tumor at the region of the basilar artery and the basilar venous plexus. Extension of endoscopic surgery posterior to this point may result in uncontrollable bleeding consequences and even brainstem hemorrhage. The preoperative MRI scan will not reflect anatomical changes due to surgical manipulations; as a result, soft tissue shifts will not be appreciated on these images.
Figure 3–3 Typical process of a patient undergoing surgery with IGS.

- Floor of the sphenoid sinus
- Anterior wall of the sphenoid sinus
- Posterior wall of the maxillary sinus
- Medial orbital wall/lamina papyracea

Shrinkage of nasal mucosa from vasoconstrictive agents applied may influence the position of the virtual point in relation to intranasal soft tissue. For example,
the mucosa of the inferior turbinate seen on a preoperative CT scan may not correlate accurately on IGS after vasoconstriction. Bony partitions will not be affected by vasoconstriction.

The DRF (headset) may be inadvertently moved due to manipulation during the operation. The resultant TRE will only be evident if constant verification is performed, as mentioned above.

For electromagnetic systems, metallic objects in the surgical field will increase TRE. For optical systems, it is essential to allow the overhead camera to see the trackers. The camera head of the endoscope may at times block this line of sight for the overhead camera.

It is important to note that structures removed during the operation are not reflected on the preoperative CT scan that is projected in the display system.

At the end of the operation, the DRF (headset) is removed, and the preoperative CT information of the patient remains within the computer workstation. This stored CT information may be reviewed at a later date.

◆ Limitations of Image-Guided Surgery

◆ Not real-time CT scan
◆ Only as accurate as slice thickness of CT scan
◆ Distance away from centroid affects accuracy.
◆ DRF shift during surgery
◆ The CT scan projected at surgery is a preoperative CT scan and not a real-time CT. Removal of tissue during surgery is not reflected on this preoperative scan.
◆ The accuracy of the system is dependent on the slice thickness of the preoperative CT. The best CT slice thickness is presently 1 mm in most centers.
◆ The accuracy of surgical navigation is affected by the distance of the localization from the centroid (point that is equidistant from all fiducial points). Thus, in most instances, TRE is lower in the anterior ethmoid than in the sphenoid.
◆ The position of the DRF may shift due to manipulation during surgery, affecting surgical navigation accuracy.
Open Sinus Surgery

William Lawson

Caldwell-Luc Procedure

The Caldwell-Luc procedure has evolved from a radical antrectomy to a minimally invasive procedure to reduce the associated operative morbidity. With chronic inflammatory disease, it is generally performed following intranasal endoscopic surgery that has been unsuccessful in eliminating chronic infection (granulomatous disease, mycotic disease, odontogenic disease). The more extensive traditional form is still used for tumor removal (inverted papilloma, angiofibroma), orbital decompression (Sewall-Walsh-Ogura procedure), and pterygopalatine fossa surgery.

Surgical Technique

- A 3 cm incision is made in the maxillary vestibule in the premolar area above the line of the attached gingiva.
- The soft tissues are divided, and limited elevation of the periosteum is performed. No attempt is made to expose the infraorbital foramen and nerve, which lie in the plane between the first and second premolars beneath the infraorbital rim. This is to avoid injury to the nerve from instrumentation or traction.
- Entry into the sinus is through the canine fossa (distal to the canine tooth) with a small gouge. Limited bone removal (1 cm) is performed with a Kerrison rongeur. The lateral wall of the maxillary sinus is covered by branches of the superior alveolar nerve, which form an extensive alveolar plexus. Minimal bone removal reduces postoperative paresthesias. The point of entry into the sinus is above the tooth root apices (~2.5 cm from the crown–root junction). This places the bone defect above the mucosal incision, avoiding the formation of a direct fistula into the sinus.
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- The sinus is surveyed with endoscopes, and selective removal of disease is performed. If most of the lining is removed, the cavity should be stripped completely to prevent the formation of a secondary mucocele in the zygomatic recess from a band of fibrosis sequestering it postoperatively.
- An antrostomy is created in the middle meatus by enlarging the natural ostium. Creation of an opening at another site in the medial antral wall will create circular movement of the secretions and promote stasis and continued infection. A small inferior meatus antrostomy may be made for temporary drainage in an essentially healthy sinus that has been entered for fracture reduction or foreign body removal. A large inferior meatus antrostomy is made for dependent drainage in a nonfunctional sinus lacking mucociliary clearance.
- The incision is closed with interrupted resorbable sutures (3–0 chromic).

◆ External Frontoethmoidectomy

The external frontoethmoidectomy is a workhorse procedure for management of a wide variety of congenital, inflammatory, traumatic, and neoplastic disorders. It permits direct access to all the ipsilateral paranasal sinuses, anterior skull base, and posterior nasal cavity. Illumination is by headlight, which may be augmented by the adjunctive use of endoscopes placed transorbitally and transnasally for magnification and angular vision. It may also be combined with other procedures (degloving procedure, Denker procedure, septectomy, medial maxillectomy) to increase surgical access and resection. It may also be used for removal of osteomas and mucoceles, resection of encephaloceles, repair of cerebrospinal fluid (CSF) leaks (especially in the narrow nose), drainage of orbital infections, orbital decompression, and management of epistaxis from trauma, or as a complication of endoscopic sinus surgery.

Surgical Technique

- A 2 to 3 cm incision is made between the eyebrow and the medial canthus, midway between the nasal dorsum and the canthus. This generally results in healing without producing a web.
- The soft tissues are divided, and the angular blood vessels are controlled by electrocautery. Bovie and bipolar cautery may be used reliably.
- The periosteum is incised, the medial canthal ligament is detached, and the lacrimal sac is elevated from its fossa and retracted laterally. Elevation and retraction of the sac do not result in dacryostenosis.
- The periorbita is elevated, which exposes the frontoethmoidal suture line, and the anterior ethmoidal artery is identified. Measurements are critical in determining the location of the ethmoidal blood vessels. The average distance from the lacrimal fossa to the anterior ethmoidal foramen is 1.5 cm; from the anterior to the posterior foramen, 1 cm; and from the posterior foramen to the optic canal, 1.0 cm. When elevating the periorbita, which is relatively dense, the herniation of fat into the operative field signals that the anterior ethmoidal foramen has been reached and impending damage to the blood vessels is likely.
Hemostasis of the anterior ethmoidal artery is by electrocautery, which leaves a burn mark on the bone that will not wash away with bleeding (clips may become dislodged). It is imperative to clearly identify the frontoethmoidal suture line, as dissection below it will prevent intracranial injury.

The lamina papyracea is exposed, and entry into the ethmoid labyrinth is made with a small punch forceps.

Bone can be removed superiorly to the frontoethmoidal suture line, inferiorly as far as the junction of the medial and inferior orbital walls, posteriorly to the ethmoidal blood vessels, and anteriorly to the anterior lacrimal crest.

The ethmoidectomy is completed, and the nasal cavity is entered.

If the frontal sinus is to be entered, dissection is performed superiorly above the lacrimal fossa. Dissection above the plane of the frontoethmoidal suture line is safe only anteriorly. A probe should be placed into the nasofrontal duct to guide dissection. Determination by imaging studies of the size and shape of the frontal sinus and whether a supraorbital ethmoid air cell is present is essential to avoid entering a cul-de-sac created by it and not the frontal sinus. The amount of frontal sinus floor that needs to be removed is variable and dependent on the pathology.

When the frontal sinus is opened, a stent of rolled thin Silastic sheeting is inserted, which extends from the frontal sinus into the nasal cavity. The middle turbinate is resected to facilitate placement and postoperative management. The Silastic tube is anchored superiorly to the subcutaneous tissues with a 4–0 Vicryl suture. It can be readily removed in the office through the nose after 6 to 8 weeks.

The periorbita is carefully realigned and closed with 4–0 Vicryl interrupted sutures that reattach the trochlea and medial canthal ligament. Suturing the periorbita with slow-absorbing sutures is sufficient for reattachment, with wire fixation unnecessary.

The subcutaneous tissues and skin are sutured in layers.

The nose is left unpacked for drainage.

Frontal Osteoplastic Flap

The frontal osteoplastic flap is the benchmark procedure for the management of chronic inflammatory disease of the frontal sinus following unsuccessful endonasal or external surgery. Creating an inferiorly based, hinged osteoperiosteal flap of the anterior table provides direct access to the sinus and all its extensions for instrumentation and obliteration. Other indications are for access to septate sinuses; removal of mucoceles, encephaloceles, osteomas, and other tumors; repair of complex fractures; and correction of pneumatoceles.

A major advantage of the procedure is that by isolating and obliterating the sinus, the need for maintaining drainage and ventilation through a patent nasofrontal outflow is eliminated—a factor limiting the success of other procedures. However, any retained epithelium in the sinus has the propensity to form a secondary mucocele. The viability of the bone flap is attested to by the absence of postoperative cosmetic deformity, although a small number of patients develop areas of resorption where periosteum has been lost, or flap enlargement (embossment) by a hyperostotic reaction.
Surgical Technique

- A coronal or direct brow (gullwing) approach may be used depending on the position of the frontal hairline. The coronal approach is preferable and should be used whenever possible not only for purposes of scar camouflage but because it permits preservation of the supraorbital and supratrochlear nerves. Transecting these nerves not only causes numbness and paresthesia of the forehead but in some patients results in a chronic local pain syndrome minimizing recurrent disease.

Coronal Approach

- The hair over the vertex of the skull is shaved for a width of 2 cm.
- The area is injected with 1% Xylocaine (lidocaine) and epinephrine 1:100,000 (~20 cc) 15 minutes before surgery. The vasoconstrictive agent markedly reduces blood loss on incising the scalp.
- An incision is made from the anterior attachment of one ear over the top of the skull to the opposite ear. This permits easy elevation of the flap down to the brow.
- The incision is carried through the galea. Hemostasis is by electrocautery (clips can also be used). The major bleeding is encountered now and can be reduced to 100 cc by preinjection.
- The plane of dissection centrally is between the galea and periosteum and laterally over the temporalis fascia. Elevation is by scalpel or Mayo scissors. Manual peeling down of the scalp will cause tearing of the periosteum, especially over the frontal bone. Care should be taken in retracting with hooks, or sharp rake retractors, so as not to injure the frontalis muscle. Bleeding during flap elevation signifies that the plane of dissection is too superficial.
- Blunt dissection and bipolar cautery are used along the supraorbital ridges to identify and prevent injury to the supraorbital and supratrochlear nerves. Bleeding in this area is usually from a blood vessel in the neurovascular bundle. After the root of the nose is exposed, the flap is folded over the face.
- A template made from a 6 foot Caldwell posteroanterior (PA) view is positioned over the supraorbital ridges and glabella, and the periosteum is incised and elevated for a few millimeters along its borders. The periosteum is treated carefully because areas of loss will result in bone resorption that may be visible. To determine that the template is accurate and there is not a magnification error, the distance between the junction of the superior and lateral walls of the orbit is measured on the patient and also on the radiograph preoperatively.
- The bone flap is created with an oscillating saw, angulating the blade to bevel the cut downward. Both supraorbital ridges are cut to a depth of 1 cm because of the thickness of the bone there. Beveling the bone cut is extremely important so as not to injure the posterior table with resultant intracranial entry. The sinus is entered by elevating the bone flap outward after dividing the interfrontal septum with a curved chisel.
- The soft tissue contents of the sinus are removed. Supraorbital ethmoid air cells are opened if present and cleared of any mucosa. The nasofrontal ducts are...
identified and debrided along with any adjacent ethmoid cells. Any remaining contiguous air cell is a potential source of reinfection of the cavity or of mucocele formation.

- The bone flap, sinus cavity, and all recesses are drilled with a large round diamond bur to remove any microscopic epithelium that may be present. Increased bleeding encountered while drilling the posterior table signifies impending dural exposure. If dural injury occurs, it is patched with temporalis fascia before the fat is placed. Drilling the bony walls partially decorticates the bone, providing a bed of capillary bleeding that helps to vascularize the fat graft. The cavity is copiously irrigated with saline.

- Temporalis fascia is harvested and used to fill the nasofrontal ducts.
- Abdominal fat is now harvested from a left subcostal incision and placed into the sinus cavity. The fat should be fresh, atraumatically removed, and not compressed when inserted into the sinus.
- The bone flap is secured with a single 28-gauge stainless steel wire placed laterally. This will not interfere with any future magnetic resonance imaging (MRI) studies.
- The periosteum is approximated with interrupted 4–0 Vicryl sutures. It is important to cover the osteotomy and any exposed bone to limit resorption.
- Rubber drains are placed, and the incision is closed with 3–0 Vicryl sutures for the galea and a continuous 2–0 Prolene suture for the skin.
- A light dressing is placed over the scalp and forehead. A compressive dressing often results in marked edema of the upper eyelids.

Direct Brow Approach

- An incision is outlined at the upper border of the unshaven eyebrow, then down into a horizontal glabellar crease and over to the opposite side.
- The skin incision is beveled, with the scalpel blade parallel to the direction of the hairs to prevent damage to the hair follicles and subsequent depilation. Incisions below the eyebrow pass through the orbicularis oculi and produce more bleeding from the muscle. Incisions in the eyebrow result in hair follicle damage.
- The incision is carried down to the periosteum. This necessitates section of the supraorbital and supratrochlear bundles with undesirable postoperative neurologic effects.
- A superior flap is elevated above the periosteum. This limits placement of the template with large frontal sinuses.
- The remaining steps are the same.

Frontal Trephine

Trephination of the frontal sinus permits entry into the sinus for biopsy, drainage of an air–fluid level in patients with acute sinusitis, and as an adjunct to intranasal
endoscopic frontal sinusotomy when the anatomy is distorted and the outflow tract cannot be safely visualized from below.

**Surgical Technique**

- A 2 cm incision is made just medial to the medial aspect of eyebrow. This avoids injury to the trochlea and supratrochlear and supraorbital nerves.
- Following division of the soft tissues, the periosteum is elevated at the junction of the medial and superior orbital walls. The frontal sinus is widest and highest at this point, ensuring entry into it.
- The frontal sinus is entered through its floor adjacent to the anterior wall with a large round bur. The bony plate is thin, permitting easy entry, and no cosmetic deformity is produced.
- The opening is enlarged to 1 cm to permit the placement of two catheters for drainage and irrigation in patients with acute sinusitis. The sinus is irrigated through the larger catheter, and fluid is evacuated through the smaller one. The incision and bony opening is smaller if the sinus is entered for localization and cannulation of the frontal outflow tract in conjunction with nasal endoscopy in patients with chronic sinusitis. The opening is larger if the interfrontal septum is to be removed for contralateral drainage or for elevation of a depressed frontal anterior table fracture.

**Intranasal Sphenethmoidectomy**

The principal method of management of chronic sinus disease is transnasal endoscopic surgery, with the extent of surgery dictated by the extent of sinus involvement. The total sphenethmoidectomy procedure, which is used by the author for patients with pansinusitis and panpolyposis, as well as for inverted papilloma, will be described. Before surgery is begun, coronal and axial computed tomography (CT) scans with bone and soft tissue windows are carefully reviewed with regard to disease extent and location and to delineate the anatomy of the sinuses (degree of sinus pneumatization, anatomical variants, position of the cribriform plate and skull base asymmetries or bony dehiscences).

**Surgical Technique**

- Surgery is performed under general anesthesia with the patient in the seated position. General anesthesia is employed for hypotension, to permit packing of the pharynx to prevent swallowing of blood with postoperative nausea, and for the introduction of bronchodilator inhalant agents should they become necessary in asthmatic patients. Hemostasis is potentiated by topical application of 4% cocaine solution and infiltration with 1% Xylocaine and epinephrine 1:100,000. The seating position is used to decrease venous drainage and to place the nasal roof parallel to the floor of the room to establish a plane of dissection directed posteriorly rather than superiorly.
- If surgical access is limited by a markedly deviated septum, this is corrected first.
Surgery is performed with both endoscopes and a coaxial headlight for magnified and true images. The 0-degree endoscope is used for the procedure to reduce optical distortion except where angular vision is required.

The middle turbinate is carefully displaced medially. If it is polypoid, markedly hypertrophic, or pneumatized, it is partially resected with a small right-angled scissors initially. Resection of the ethmoid labyrinth is performed only lateral to the middle turbinate to prevent injury to the cribiform plate.

If the uncinate process is well pneumatized, it is incised with a Freer elevator (never a knife) and removed. Otherwise, the ethmoid bulla is entered first, and the uncinate process is removed retrograde with a backbiting forceps to prevent entry into the orbit by injury to the lacrimal bone. Dissection posteriorly is in a downward direction as the nasal roof descends to the sphenoid.

The ground lamella is removed, and the posterior ethmoid cells are entered. Instrumentation is with small grasping forceps (straight and angled) by teasing soft tissue and bony septa and not with punch forceps. If any resistance is encountered, a probe is used to ascertain that bone is present behind the soft tissue and not exposed dura.

After the initial entry into the ethmoid labyrinth is made, the principle of triangulation of landmarks is used. The natural ostium of the maxillary sinus is sounded in the middle meatus and is enlarged with biting forceps. This establishes the plane of the lamina papyracea and the limit of lateral dissection of the ethmoid labyrinth. The middle turbinate is partially excised to expose the face of the sphenoid bone. The sphenoid sinus ostium is identified with a beaded border probe adjacent to the nasal septum on a horizontal plane with the maxillary sinus ostium and at an angle of 30 degrees from the anterior nasal spine. The mean distance to the ostium is ~7 cm. The ostium is located medial and slightly above where the middle turbinate attaches to the sphenoid face. The ostium is enlarged with a punch forceps and the cavity aspirated, with hypertrophic tissue carefully removed. The face of the sphenoid sinus is generally the posterior limit of ethmoid dissection. Identification and opening of the sphenoid ostium permits the safe removal of posterior ethmoid cells overlying the sphenoid anteriorly. Dissection behind it is hazardous because instrumentation of an Onodi cell may cause injury to the optic nerve, or possibly CSF leak. Similarly, instrumentation above the sphenoid ostium is dangerous because of the proximity to the cribiform plate. Dissection of the labyrinth is now carried anteriorly, removing the remaining diseased soft tissues and bony septa. The frontal recess is identified and minimally instrumented to prevent iatrogenic nasofrontal outflow scarring and stenosis.

Total ethmoidectomy entails removal of the ground lamella of the middle turbinate, which destabilizes it, with lateral migration of the turbinate carrying the potential for middle meatus obstruction. Partial turbinectomy prevents this and also facilitates intraoperative instrumentation and visualization, as well as postoperative care of the surgical cavity.

Hemostasis posteriorly is by suction electrocautery. Polypoid tissue beneath the sphenoid ostium may be electrocauterized, as avulsion or tearing may cause profuse bleeding from the sphenopalatine artery.

A light packing of Vaseline™ or antibiotic-impregnated gauze is placed for 24 hours.
Antrostomy

Historically, an opening was made in the nasoantral party wall in the inferior meatus by puncture for irrigation, and an osteotomy was created for dependent drainage. Recognition of the pattern of mucociliary flow spiraling to the natural ostium led to the physiologic creation of a middle meatus antrostomy under endoscopic guidance. In a small number of patients, a temporary antrostomy is created inferiorly for the evacuation of blood following fracture reduction, or removal of an antral foreign body, or dentoalveolar lesion, so as not to disturb the natural ostium and disrupt normal mucociliary clearance. In patients having undergone the Caldwell-Luc procedure or maxillary surgery with entire loss of a functional mucosa, a permanent inferior meatus antrostomy is performed.

Surgical Technique

- Anesthesia is obtained by topical application of 4% cocaine followed by infiltration with 1% Xylocaine and epinephrine 1:100,000.
- An attempt is made to visualize the natural ostium in the hiatus semilunaris of the middle meatus with a 30-degree endoscopic probing with an ostium seeker. Anatomical studies have shown that this is not always possible because of anatomical variations. The ostium may also be obliterated by disease. In some patients a prominent uncinate process is obstructive and may require removal for exposure of the ethmoidal infundibulum. Also, an accessory ostium may be present and be mistaken for the primary opening. It is important to identify the primary ostium because failure to identify and enlarge it, or creating a false opening, will result in circular motion of sinus secretions and failure of mucociliary clearance.
- When the ostium is identified (visualized or sounded), it is enlarged by removing portions of the membranous meatus with punch forceps. Anteriorly, this is performed with a backbiting forceps. Bone should not be aggressively removed to avoid injury to the nasolacrimal duct. This is located 1 cm behind the anterior attachment of the middle and inferior turbinates before it enters the inferior meatus.
- When the ostium cannot be identified, the antrum is entered with an olive-tip curved suction introduced at the attachment of the inferior turbinate at its midportion and directed downward. In patients with hypoplastic maxillary sinuses, the ethmoidal infundibulum may be dangerously close to the orbit. The antrum should be entered in the inferior meatus (see below) and sounded to determine if and where a middle meatus opening is to be made. This may also be necessary in the partially pneumatized antra of pediatric patients.
- A small amount of Vaseline or antibiotic-impregnated gauze is inserted in the middle meatus overnight for hemostasis. During the procedure, care is taken not to abrade the middle turbinate to avoid adhesions in the middle meatus.
- If an inferior meatus antrostomy is to be created, the point of antral entry is at the midpoint of the attachment of the inferior turbinate to the lateral wall. The bone of the inferior meatus is thinnest in this area, and penetration into the sinus can be made with a curved suction or trocar. Bone is removed anteriorly and
posteriorly with punch forceps. A minimal opening of 1 cm is made, as postoperative narrowing universally occurs. Again, a light dressing of lubricated ribbon gauze is placed.

◆ Repair of Oro-Antral Fistula

A communication between the maxillary sinus and the oral cavity most commonly occurs through the alveolus secondary to dental extraction. The major predisposing factor is chronic maxillary sinusitis, which is often subclinical and unrecognized, that gains dependent drainage through the tooth socket. The roots of the molar teeth commonly extend into the maxillary sinus, and the extraction sites routinely heal uneventfully. However, when pulpal and periodontal disease produces alveolar osteitis and bone loss, a sino-oral communication persists. Other pathogenic factors include the presence of foreign bodies (dental implants, sinus lift grafting materials), systemic disease (diabetes, autoimmune disorders, immunodeficiency states), and radiotherapy.

The high failure rate of closure of oro-antral fistulas is due to the presence of uncorrected chronic sinus disease. CT scanning of the paranasal sinuses delineates the extent of sinus pathology and serves as a guide to adjunctive endoscopic surgery following medical therapy. Patients with fistulas that persist after systemic antibiotic therapy and antral irrigations almost invariably have chronic sinusitis. The method of repair the author employs is predicated on the complete removal of the diseased antral mucosa with concomitant closure of the fistula with a buccal advancement flap.

Surgical Technique

◆ After the induction of general anesthesia, the maxillary vestibule and nasal cavity are infiltrated with 1% Xylocaine and epinephrine 1:100,000.

◆ Three vertical incisions are outlined in the maxillary vestibule. The anterior one is slightly distal and parallel to the canine tooth. The anterior border of the maxillary sinus is the canine tooth. The two posterior incisions are made at the borders of the fistula and diverge slightly. The anterior incision is over the canine fossa and permits entry directly into the maxillary sinus. A conventional horizontal incision across the vestibule would prohibit the creation of a buccal advancement flap.

◆ The mucoperiosteum is elevated over the canine fossa, and the antrum is entered with a mallet and gouge. A limited amount of bone (1 cm) is removed with a Kerrison rongeur. The sinus is inspected with endoscopes, and the diseased mucosa and any foreign material are removed. A middle meatus antrostomy is created and ethmoid sinus disease exenterated. If total removal of the antral lining is necessary, an inferior meatus antrostomy is created for dependent drainage.

◆ The fistula tract is incised with a no. 11 blade, and the bone margins are curetted. If the exposed root of a tooth forms part of the tract, it is extracted to obtain circumferential bony and soft tissue margins for the closure.

◆ The two posterior incisions are made through the mucoperiosteum, which is mobilized off the alveolus with a Freer elevator.
The periosteum on the undersurface of the flap is incised transversely with a no. 15 blade. This is essential for the release of the flap so that it may be advanced over the defect tension-free.

The buccal flap is sutured with 3–0 Vicryl on an atraumatic needle to the palatal, alveolar, and vestibular soft tissues.

A Vaselinized gauze pack is placed in the nose for 24 hours. The patient is maintained on clear fluids and a soft diet for a week. Hydrogen peroxide mouth rinses are used following meals. The nose is endoscopically cleansed and the antrum aspirated at 1 week.
Transnasal and Transethmoidal Approaches to the Sella Turcica

K. J. Lee and Nilesh R. Vasan

The transseptal transsphenoidal approach to the pituitary is the most common method used by otolaryngologists for access to the pituitary gland. The procedure requires a two-team approach, with the otolaryngologist providing access for the neurosurgeon to remove lesions within the sella turcica.

◆ Preoperative Evaluation

Imaging

◆ Magnetic resonance imaging (MRI) to assess the lesion within the sella and brain
◆ Computed tomography (CT) scan to determine the anatomy within the nasal cavity, paranasal sinuses, and skull base. Information regarding access to the sphenoid sinus is provided by fine-cut coronal CT images.

General Considerations

◆ A grossly deviated septum, previous surgery, or nasal polyposis can complicate the operation, and other surgical approaches to the sphenoid may need to be considered (e.g., transethmoidal approach). Alternatively, procedures to correct these abnormalities may be required.
◆ Any bleeding disorder must be correctly diagnosed and managed prior to the operation. Excellent hemostasis is vital to perform this operation safely.
Chapter 5 Transnasal and Transethmoidal Approaches

◆ Surgical Technique

Transnasal Approach

◆ All CT and MRI scans must be available for review in the operating room.

◆ Following induction of general anesthesia (GA), the otolaryngologist prepares the nose with Afrin® (oxymetazoline) nasal decongestant and then infiltration of the septum with 1% Xylocaine (lidocaine) and 1:100,000 epinephrine. It is important to infiltrate low within the nose, including the nasal floor. The nose can then be packed with Afrin-soaked cottonoid pledgets. Alternatively, 3 to 4% cocaine-moistened pledgets may be used to pack the nose. Always remember to inform the anesthetist of what type of local anesthetic (LA) and dosage is placed within the nose to avoid cardiovascular side effects.

◆ Approximately 15 minutes should elapse to ensure good hemostasis that is mandatory for the safe execution of this operation. The neurosurgeon can insert the lumbar drain during this interval.

◆ The patient is then positioned with the head slightly extended. In all cases, good, comfortable access to the nose, particularly when using the microscope, for both otolaryngologist and neurosurgeon is helpful.

◆ An operating microscope with an angled eyepiece and 400 mm objective lens is used.

◆ Image-guided systems allow the surgeon to correctly and safely access the sphenoid, as it accurately depicts the position of the intersinus septum and thus greatly reduces the risk of inadvertent injury to the carotid artery and cranial nerves.

◆ The patient is then prepped and draped. This includes an area of the abdomen for harvest of a fat graft to the sphenoid if required. Towel clips are avoided at the head because they interfere with intraoperative lateral radiography should this be used instead of an image-guided system. Drapes are sutured, or the adhesive variety is used.

◆ Making a left hemitransfixion incision for a right-handed surgeon is usually easier. The mucoperichondrium must be elevated completely superiorly and especially inferiorly along the floor of the nose to allow access for the Lee or Hardy speculum.

◆ The mucoperichondrial flap is elevated with either a Freer or Cottle elevator. The mucoperichondrial and mucoperiosteal flap is completely elevated on the left side, and the bony-cartilaginous junction is divided. The mucoperiosteal flap on the right side is then elevated, thus isolating the bony septum. If possible, the right mucoperichondrium flap is not elevated. This is to allow preservation of a normal anatomical plane should revision surgery be required. Care must be taken not to perforate the flap if possible. If the septum is grossly deviated, correction of the deformity using standard septoplasty techniques may be undertaken at this time. This will improve access for the surgeon. The quadrangular cartilage must be completely disarticulated from the maxillary crest to allow insertion of the speculum.

◆ When the sublabial approach is used, inserting a Freer dissector through the anterior nasal floor to communicate with the sublabial area makes access to this plane easier. Using the Freer dissector as a guide, the sublabial incision is made with a Bovie knife. An incision is made above the gingiva to leave a cuff of mucosa on the gingival side for easier wound closure later.
The nasal spine is identified and isolated with iris scissors. It is divided at its base with an osteotome, leaving it attached via its connective tissue. Some surgeons remove the spine; however, leaving the nasal spine allows easy reapproximation of the caudal septum to the spine at the completion of the operation.

A speculum is then inserted into the nose via the sublabial incision. Difficulty with insertion is usually due to inadequate elevation of the floor of the nose mucoperiosteal flap, too small a sublabial incision, or possibly too large a speculum. The speculum must be correctly inserted, with the serrated edges placed inferiorly along the floor of the pyriform aperture.

Alternatively, the method described by the senior author (KJL) can be used. Once the hemitransfixion incision has been made and the mucoperichondrial flap elevated past the perpendicular plate of the ethmoid, the sublabial incision is performed. The pyriform aperture is identified, and the mucous membrane along the floor of the nose is elevated, creating an inferior tunnel. Using a Cottle or McKentry elevator, the caudal aspect of the septum is identified through the sublabial incision. The inferior tunnel is then connected to the elevated mucoperichondrial flap. A Freer septal “D” knife is ideal for this purpose.

An inferior tunnel is made in a similar fashion in the contralateral nasal airway; however, the full mucoperichondrial flap is not elevated on the contralateral side because this would violate a potentially unoperated area for future access if the pituitary tumor should recur. Also, elevation of bilateral mucoperichondrial flaps could risk avascular necrosis of the quadrangular cartilage and perforation if the flaps are not adequately reapproximated. Removal of the anterior nasal spine facilitates exposure.

The senior author (KJL) has previously described widening and lowering of the pyriform aperture using a powered drill to accommodate the Lee (or Hubbard) self-retaining speculum, as the width of the speculum blade is limited anteriorly by the pyriform apertures and by the midportion of the medial pterygoid plates posteriorly. When using a non-Hardy speculum, if the pyriform aperture and the region of the anterior nasal spine are not lowered sufficiently, the speculum will be misdirected inferior to the sella. Prior to insertion of the speculum, the septum must be dislocated off the maxillary crest.

Using nasal scissors, the perpendicular plate of the ethmoid is divided high posteriorly and the bony septum removed with Takahashi forceps. This is preferable to forceps removal of the perpendicular plate because overexertion here may cause a cerebrospinal fluid (CSF) leak from the cribriform plate area. A straight vomer may be left, which is a good landmark to follow to the midline of the sphenoid. All bony/cartilaginous fragments must be kept in saline for use by the neurosurgeon as packing material within the sphenoid sinus after tumor removal.

Using the longest Cottle speculum, the vomer can be removed to the sphenoid rostrum safely without the use of a microscope in many instances. The mucoperiosteum is reflected laterally off the face of the sphenoid to allow identification of the sphenoid ostia. The correct level of entry into the sphenoid sinus or sella can be confirmed by the image-guided system or by use of intraoperative lateral videofluoroscopy using a metal probe.
After the sphenoid ostia have been identified, the smallest Kerrison rongeur is inserted into the ostia and the sphenoid bone removed in an inferior-medial direction from both sides. This will avoid injury to neurovascular structures. Larger Kerrisons are then used to widen the sphenoidotomy.

Under magnification, the sphenoidotomy can be further widened, leaving a small cuff of bone at the periphery of the sinus that will help to secure the packing tissue within the sinus.

The surgeon must be aware that the intersinus septum is rarely in the midline, and this may confuse the surgeon as to the location of the sella turcica. Close attention to coronal CT scans and/or intraoperative image-guided systems will help identify the intersinus septum for its removal. The sinus mucosa must be completely stripped to avoid potential complications such as mucocele formation.

The neurosurgeon then removes the pituitary lesion and packs the sphenoid sinus with the fragments of cartilage and bone harvested from the septum. Occasionally, a fat graft from the abdomen is used to complete packing of the sinus to avoid a CSF leak. It is important to have all sutures and nasal cavity packing material ready as the neurosurgeon completes his or her part of the procedure because unnecessary delay could lead to dislodging of the grafts within the sinus or bleeding. Also, the surgeon should avoid suctioning in the area of the sinus for similar reasons.

The caudal septum is reattached to the nasal spine with 3–0 Vicryl or chromic catgut. It is important not to have perforated flaps in direct opposition on the cartilaginous septum because this may result in a septal perforation. It would be better to close the hole on one side with 4–0 chromic sutures to avoid this. The hemitransfixion incision is repaired with 3–0 plain catgut, and the septum is reapproximated with 3–0 chromic mattress sutures.

Silastic septal splints are inserted bilaterally and loosely secured with 3–0 nylon sutures to the anterior septum. Alternatively, Telfa strips can be placed just lateral to the septum. Both nasal cavities are then packed with either Merocel nasal packs or antibiotic- (and/or Vaseline-) coated ribbon gauze. Care should be taken not to pack the nose too tightly, as this may risk pressure necrosis of the septum and subsequent septal perforation.

The patient should remain on antibiotics and the nasal packs removed in 5 to 7 days. The splints should be removed in 10 to 14 days.

Revision Transseptal Approach to the Pituitary or Previous Septoplasty

In cases of previous septoplasty, it is hoped that the cartilaginous septum and some bony septum have remained. Elevation of the flap should be performed on the contralateral side to minimize dissection in fibrotic tissue. If possible, a tissue plane may be identified with careful dissection between the flaps. This would be relatively easier if some bony component of the septum has been left from which a flap can be raised. In almost every case, the septum will be left with numerous holes, and careful reapproximation of the flaps is required at the end of the procedure.

In revision pituitary cases or in septoplasty procedures where the perpendicular plate has been entirely removed, consideration should be given to other surgical techniques.
Figure 5–1 Incision for transethmoidal approach. (Used with permission from Jafek BW, Sasaki CT. The Atlas of Head and Neck Surgery. New York: Grune & Stratton; 1983:163.)

Figure 5–2 Exposure of ethmoid bone. (Used with permission from Jafek BW, Sasaki CT. The Atlas of Head and Neck Surgery. New York: Grune & Stratton; 1983:163.)
approaches to the pituitary. Due to the fibrosis of the membranous septum posteriorly, it is nearly impossible to separate these flaps. In these situations, the anterior mucoperichondrial flap can be raised to allow insertion of the speculum either transnasally or sublabially. The septal flap is then divided vertically just posterior to the cartilage to allow passage of the speculum toward the sphenoid sinus. Image guidance and/or videofluoroscopy are essential in these cases. Once the sphenoid rostrum has been identified, the mucoperiosteum is reflected off the face of the sinus and the sphenoid entered via the sinus ostia, as previously described. If the ostia are not easily identified, then with the aid of intraoperative imaging, the sinus can be entered inferiorly in the midline. In some cases, the speculum may be inserted without raising a flap anteriorly; however, access is limited, and the nose may be unduly traumatized.

Following removal of the tumor and the packing of the sinus, care must be taken in reapproximating the septum and/or flaps. Usually, the septum has suffered numerous perforations, and the surgeon must remember that the septum has been separated from the face of the sphenoid sinus. The septum is bolstered together with chromic sutures, as described above; however, in these cases a long posterior septal Silastic® splint is imperative. The splint should reach the sinus, where it acts to support the residual septum against the sphenoid rostrum and thereby maintain pressure on the packing grafts within the sinus. The nose should then be packed with antibiotic-coated ribbon gauze, as this allows better placed posterior packing compared with Merocel® packs.

**Transethmoidal Approach**

- The patient is prepped, draped, and positioned as in a routine septorhinoplasty. During the draping, it is important to avoid any metallic towel clips so as not to interfere with any intraoperative x-ray films. The incision is made as outlined in Fig. 5–1.

- A temporary tarsorrhaphy is performed. With the Freer or Cottle elevator, the ethmoid bone is exposed and the orbital contents carefully protected using an orbital retractor (Fig. 5–2). When retracting the orbit, it is necessary not to apply too much and too constant a pressure.

- The lacrimal fossa is identified, as well as the anterior ethmoidal artery. It is cross-clamped with hemoclips and transected (Fig. 5–3).

- The anterior ethmoid sinus is opened with bone curets (Fig. 5–4).

- With Kerrison rongeurs, the area is widened to allow access to the anterior and posterior ethmoid sinuses.

- Through this approach, the sphenoid sinus is encountered and entered, exposing the sella turcica. The mucosa of the sphenoid sinus is stripped. Intraoperative, across-the-table lateral skull x-ray films may be needed to determine the exact position of the sella. After this is ascertained, the posterior wall of the sphenoid sinus is removed with rotating burs, curets, or hypophysectomy rongeurs. It is necessary to avoid injury to the circular sinuses to prevent troublesome bleeding. Bleeding can be controlled at this stage with bipolar cautery or Surgicel® packing.
Figure 5–3 Exposure of lacrimal fossa and division of anterior ethmoidal artery. (Used with permission from Jafek BW, Sasaki CT. The Atlas of Head and Neck Surgery. New York: Grune & Stratton; 1983:164.)

Figure 5–4 Curetting into anterior ethmoid sinus. (Used with permission from Jafek BW, Sasaki CT. The Atlas of Head and Neck Surgery. New York: Grune & Stratton; 1983:164.)

- The path taken in the transethmoidal transsphenoidal approach to the sella is shown in Fig. 5–5.
- Subsequent to the neurosurgical procedure, fascia taken from the upper right thigh is placed over the sella region, and the sphenoid sinus is packed with adipose connective tissue. Care is taken to ascertain that all the mucosa of the sphenoid sinus...
has been removed. Surgicel packing is used in the sphenoid and ethmoid sinus regions to control troublesome oozing. A Cottle speculum is used to visualize through the nasal cavity to inspect the operative site. Surgicel packing may be introduced through the nasal cavity to further close the surgical wound.

Figure 5–5 Path taken in the transtethmoidal transsphenoidal approach to the sella. (Used with permission from Jafek BW, Sasaki CT. The Atlas of Head and Neck Surgery. New York: Grune & Stratton; 1983:164.)

Figure 5–6 Closed transtethmoidal incision with rubber drain in place. (Used with permission from Jafek BW, Sasaki CT. The Atlas of Head and Neck Surgery. New York: Grune & Stratton; 1983:165.)
intranasally. Occasionally, small amounts of Nu-gauze® impregnated with bacitracin ointment may be necessary for nasal packing for 2 or 3 days. (Prior to use, the fascia and adipose connective tissue harvested from the upper right thigh are bathed in a solution of streptomycin, 50 mg in 1000 mL normal saline or in a solution of bacitracin, 100,000 units in 1000 mL normal saline.)

◆ The incision is closed with interrupted 3–0 chromic sutures and interrupted 5–0 nylon sutures with a small rubber drain in position (Fig. 5–6). The temporary tarsorrhaphy sutures are removed, and eye pads are used to form a gentle pressure dressing. Postoperative antibiotics are advocated for 7 days; the choice of antibi-otic therapy is guided by preoperative nasal culture. The patient is to refrain from physical exertion as well as from stooping forward. The patient is kept in the semi-Fowler position for 72 hours postoperatively and is advised to keep the head of the bed elevated for the next 2 weeks.
Preoperative Considerations

If a patient experiences brisk or prolonged blood loss, observe closely for postural hypotension, which may require careful rehydration with intravenous fluids.

Control of hypertension is usually essential for epistaxis management. Some patients have hypertension-dependent cerebral blood flow, and hypertension control should be achieved with continuous input from the primary care physician (PCP) or emergency room physician.

The patient receiving therapeutic anticoagulation/antiaggregation therapy (i.e., warfarin or aspirin) deserves special mention. Evaluation of the risk/benefit ratio of discontinuing therapy must be reached in close communication with the patient’s PCP/cardiologist as appropriate.

Topical anesthesia and vasoconstrictors are pharmacological agents that can be very helpful in the initial treatment of epistaxis.

- Maximum doses
  - **Cocaine** 1 mg/kg body weight
  - **Lidocaine** 4 mg/kg body weight for infiltration alone or 7 mg/kg in combination with epinephrine

- Silver nitrate (AgNO₃) is best used for modest bleeding from Kiesselbach’s plexus when the site is clearly visualized.
  - Anesthetize the mucosal surface to be cauterized before carrying out the cauterization procedure.
  - Avoid accumulation of AgNO₃ around the nasal vestibule/ala to avoid discoloration of the skin.
Apply petroleum-based antibiotic ointment to the cauterized septal area to minimize the risk of synechiae formation with the turbinate.

◆ Nonoperative Treatment

Nasal Packing

- Nonabsorbable packing materials include Merocel® (medtronic corp., minneapolis, MN), Rapid Rhino® (arthrocare corp., austin, TX), Epistat® balloon, and conventional anteroposterior (AP) petroleum jelly gauze strips.
- Lubricate these before application and moisten them before removal.
- Packing should be left in place for up to 3 to 5 days to allow for mucosal reepithelialization.
- Patients who undergo AP nasal packing should be admitted to the hospital to be monitored continuously for apnea and blood oxygen saturation variations mediated via the nasopulmonary (NP) reflex. The NP reflex has been well documented to cause hypoxemia and hypercarbia. This is especially important in the patient with chronic obstructive pulmonary disease (COPD).

AP Nasal Packing

- Anterior nasal packing is attempted first. If unsuccessful, AP packing is indicated.
- A 14-gauge Foley catheter is passed through the nasal passage with the heaviest bleeding until seen in the oropharynx. Ten milliliters of sterile water is injected into the Foley catheter balloon, and the catheter is gently withdrawn until resistance is met. Sterile water will not crystallize (unlike saline) and is noncompressible (unlike air).
- Special care is taken to ensure protection of the nasal ala/columella. A portion of the catheter is trimmed off and skewered onto itself prior to its insertion through the nose for this purpose.
- Petroleum jelly-gauze or Xeroform® packs are used to pack the anterior nasal cavity in a systematic (anterior to posterior and inferior to superior) layered fashion.
- A C-clamp is fitted over the Foley/guard complex, securing the packing in place, and ensuring decreased pressure on the ala/columella.
- For conventional packing, a dental roll will have a similar function with the strings tied over the dental roll.
- Patients who undergo any type of nasal packing should be placed on antibiotics covering gram-positive organisms to avoid toxic shock syndrome.

◆ Operative Management

Approximately 10% of patients will fail the nonsurgical treatment outlined above. Indications for surgical management include the following:

- Persistent bleeding in spite of conventional AP nasal packing
- Patient refusing or not tolerating packing
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- **Anatomical abnormality making nasal packing impossible.** (i.e., significant septal deviation)
- **Concern for presence of neoplasm**

Operative management for epistaxis is aimed at interrupting or significantly decreasing blood flow to the bleeding site. This requires being able to localize the exact bleeding site or assessing the general region from which bleeding may be originating.

**Anterior Bleeding**

- Recurrent anterior bleeding usually originates from Kiesselbach’s plexus and responds well to electrocautery.
- Care should be taken during cauterization of the nasal septum to avoid creating a septal perforation. Cautery of mucosa should be performed with a light touch so as to prevent adhesions of the blade to the mucosa. Releasing the cautery from the mucosa often results in more bleeding.
- The Bovie blade is preferred over the needle-tip, which is sharp. The blade should be insulated up to a few millimeters from the tip. Suction cautery is also likely to adhere to the nasal mucosa; use separate suction tip if necessary.
- Bilateral septal cautery is appropriate if cauterization on directly opposing septal surfaces is avoided.

**Posterior Bleeding**

- Posterior nasal circulation arises from the external carotid artery and includes the sphenopalatine artery (SPA), greater palatine artery, ascending pharyngeal artery, posterior nasal artery, and superior labial artery.
- Direct identification of posterior bleeding is sometimes possible with the use of nasal endoscopy. This is a situation when the suction cautery is best used.
- Proper identification of the bleeding site may be challenging in patients with bleeding arising posteriorly to marked septal deflections. Some will require concurrent septoplasty.

**Transnasal Endoscopic Sphenopalatine Artery Ligation**

- This procedure targets the SPA as it enters the nasal cavity between the middle and inferior turbinates 5 to 10 mm posterior to the level of the posterior wall of the maxillary antrum.
- Neurosurgical patties soaked in a 4% cocaine solution are placed in the middle meatus as well as against the inferior and middle turbinates.
- Infiltrate lidocaine 1% with epinephrine 1:100,000 in the middle turbinate and lateral nasal wall in the region of the uncinate process. Repack with the cocainized pledgets and wait 10 minutes (prep/drape patient during this time).
- Perform standard uncinectomy, followed by a wide middle meatal antrostomy created with a through-cutting forceps back to the level of the posterior wall of the maxillary antrum. This aids in the surgical exposure as well as in gauging the proximity to the posterior wall of the maxillary antrum.
A vertical mucoperiosteal flap is elevated medially with the use of a Cottle elevator within the nasal cavity. Care is taken to identify the SPA vessel at its entry point into the nasal cavity from the pterygopalatine fossa. Double clipping with or without diathermy of the SPA is performed. Postoperative nasal packing is not required. Occasional minor complications include nasal crusting (34%), palatal numbness (13%), acute sinusitis (3%), decreased lacrimation (3%), and septal perforation (3%). The major limitation of endoscopic arterial ligation is the presence of nasal packing. When removal of packing results in uncontrollable hemorrhage, a transantral approach is preferred.

Transantral Internal Maxillary Artery Ligation

This procedure targets the internal maxillary artery (IMA) within the pterygomaxillary fossa. IMA ligation requires microscopic dissection/clipping of the IMA and its branches within the pterygomaxillary fossa. A Caldwell-Luc approach is required and carries potential complications related to infraorbital nerve injury, oro-antral fistula formation, and neurovascular injury to the teeth. The operating microscope is used with a 300 mm lens. The authors recommend the McCabe antral retractor be employed for adequate exposure. The posterior wall of the maxillary sinus is visualized. Removal of the mucosa of the posterior sinus wall is necessary; once the mucosa is stripped away, cocaine-soaked packing is applied to the maxillary sinus. This provides a dry surgical field. Two parallel vertical lines and two parallel horizontal lines are scored onto the bone of the posterior wall of the maxillary antrum, thereby re-creating a tic-tac-toe grid with nine “squares.” Removal of the bony wall of the middle-medial square is performed with a diamond bur, keeping the following caveats in mind:

- If the bone of the superior-medial square is removed, the ethmoid air cell system will be entered.
- Drilling away the inferior-medial square may result in brisk bleeding from the descending palatine artery.
- The middle-medial square separates the antrum from the sphenopalatine artery.

Hypophysectomy instruments (elevators and hooks) with their long handles are ideal for dissection within the fat of the pterygomaxillary space. A blunt elevator is used to tease fat away from the vascular structures. Once identified, the vessels are lifted toward the surgeon using a blunt hook. Although the vidian nerve is located posterior to the level of dissection, injury is possible and should be avoided by careful dissection and clearly identifying that the structure to be ligated is vascular.
At least three vessels should be clipped, with a clip placed on each side of the hook. Cautery should be avoided to minimize the risk of nerve injury.

A meatal antrostomy is performed to ensure postoperative drainage of antral contents.

At the end of the procedure, packing is removed to be sure the bleeding is controlled. When the ligation is somewhat distant from the bleeding site, collateral circulation (even from the counterlateral side of the nose) may allow further bleeding to occur.

External Carotid Artery Ligation

- External carotid artery (ECA) ligation targets the ECA anterior border of the [sternocleidomastoid (SCM)].
- Local or general anesthesia may be used.
- A horizontal skin incision is made between level of the hyoid and the superior border of the thyroid cartilage. Subplatysmal flaps are raised, and the SCM is retracted posteriorly, allowing good exposure. The carotid sheath is picked up with a DeBakey forceps and carefully opened with a slightly open Metzenbaum scissors. Care is taken not to disrupt any of the contents of the carotid sheath during this maneuver.
- Identification of the ECA (multiple branches) from the internal carotid artery (ICA; no extracranial branches) is critical. Ligate the ECA distal to the superior thyroid artery.
- The sympathetic cervical chain is usually located along the posterior aspect of the common carotid artery. Dissection into this area is usually not necessary and avoids injury to the sympathetic chain with subsequent ptosis, myosis, and anhidrosis of the ipsilateral hemiface (Horner’s syndrome).
- Ensure cranial nerves X and XII are identified and preserved before ligating the vessel.
- Effectiveness is suboptimal because of how proximally the artery is ligated, allowing for collateral flow distally.
- Consider this procedure for patients with high surgical risk.

Anterior Circulation

Anterior/Posterior Ethmoidal Artery Ligation

- Anterior ethmoidal artery (AEA) and posterior ethmoidal artery (PEA) litigation targets anterior circulation (arising from the ophthalmic artery via the ICA).
- Creating a temporary tarsorraphy ensures corneal protection.
- A skin incision is made at a point equidistant between the nasal dorsum and the medial canthus (Lynch incision), and is carried down to the nasal bone.
- Avoid using monopolar cautery once in the orbit.
- Periosteal elevation is performed aimed at the lower portion of the medial orbital wall.
- The lacrimal crests (anterior and posterior) are identified, and the lacrimal sac (within the lacrimal fossa) is gently retracted laterally.
A slotted orbital retractor allows dissection posterior to the AEA, which should be found ~22 mm (range of 16–29 mm) posterior to the anterior lacrimal crest. The artery is double clipped and handled gently, taking care not to traumatize/avulse it.

If epistaxis does not resolve by ligating the AEA, ligation of the PEA may be performed. However, the smaller caliber of the PEA makes it a less likely source for any clinically significant epistaxis.

The PEA can be located ~8 to 12 mm posterior to the AEA.

An additional reason not to dissect the PEA unnecessarily is its close relation to the optic nerve. The optic nerve can be located ~4 to 6 mm posterior to the PEA.

The authors recommend leaving a sterile rubber band in place as an open drain system.

Care is taken to place a dressing over the wound but away from the cornea before the tarsorrhaphy suture is released.

Ligation of the AEA can also be performed endoscopically. The artery courses in a medial to lateral direction from the orbit into the ethmoid bone, coursing along the roof of the ethmoid. It can be found by tracing the anterior face of the bulla ethmoidalis superiorly, and then observing a few millimeters posteriorly. However, its anatomical relation to the ethmoid bone/orbit as well as the fragile bone surrounding the vessel makes it especially prone to complications, including iatrogenic dural injury with subsequent cerebrospinal fluid leak and or intraorbital arterial avulsion with orbital hematoma formation.

**Laser and Septodermoplasty (Hereditary Hemorrhagic Telangiectasia/Osler-Weber-Rendu disease)**

- This procedure removes nasal mucosa from the anterior septum, floor of the nose, and lateral nasal wall.
- Lateral rhinotomy or alotomy is required for exposure in septodermoplasty.
- Neodymium-yttrium-garnet (Nd-YAG) laser and argon laser are used because of their preferential absorbency by hemoglobin, making them especially useful for coagulation and hemostasis.
- Laser and septodermoplasty are aimed at decreasing the frequency and severity of epistaxis but may not correct the problem altogether.

**Arterial Embolization**

- Arterial angiography and selective embolization are indicated in patients with a high risk/benefit ratio for receiving anesthesia or those who refuse surgical intervention.
- The low but real risk of cerebrovascular accidents, retinal artery occlusion secondary to silent ECA to ICA anastomosis, and potential for renal insult secondary to contrast media should usually make surgical therapy a preferred management option.
- Recent studies have shown the effectiveness of endoscopic SPA ligation to be higher than IMA embolization, without the risks of strokes associated with the former.
◆ **Key Points**

◆ A thorough evaluation will be helpful in pointing out likely predisposing and precipitating causes of epistaxis, as well as guiding the initial course of action.
◆ Epistaxis caused by a reversible medical condition should be treated medically if not otherwise contraindicated.
◆ Epinephrine and cocaine cause tachycardia and increase myocardial contractility and oxygen demand, all of which can be of risk to the patient with underlying coronary artery disease.
◆ Nonabsorbable nasal packing should be left in place for up to 3 to 5 days to allow for mucosal reepithelialization. Absorbable packing should be used as “surgical dressing.”
◆ The efficacy of surgical management of epistaxis will always be dependent on identifying the exact bleeding site and interrupting blood flow as close to the bleeding site as is technically possible.
Repair of Choanal Atresia

William Lawson

Choanal atresia is generally unilateral and predominantly bony in nature. In infants, the life-threatening nature of the condition requires immediate correction, which is generally performed by transnasal perforation and curettage of the atretic area. Despite prolonged stenting, many cases subsequently require revision in later childhood, often by a transpalatal approach.

◆ Surgical Approaches
◆ Endoscopic transnasal approach
◆ Transpalatal approach

◆ Surgical Technique

Endoscopic Transnasal Approach
◆ Conventional and powered instrumentation may be used.
◆ This approach provides better visualization and tissue removal, with a high degree of success.

Transpalatal Approach
The transpalatal approach offers wide exposure, may be used for unilateral and bilateral cases, permits total removal of obstructing bony plates, and is mucosal sparing, which reduces the stenting time. It is the method of choice for revision
cases. Its potential disadvantages are growth disturbance in young individuals and palatal muscle dysfunction. Accordingly, the author favors this approach with bilateral and bony atresias and for revision cases in older individuals.

- After the induction of general anesthesia, a Crowe-Davis mouth gag is introduced. The incision is outlined and infiltrated with 1% Xylocaine (lidocaine) and epinephrine 1:100,000.
- A U-shaped incision is outlined at the junction of the hard palate and maxillary alveolus. This provides wide exposure of the posterior choana and nasopharynx and avoids the potential complications of fistula and soft palatal scarring of the vertical incision. It extends from the maxillary tuberosity, anteriorly behind the incisor teeth, to the opposite tuberosity.
- The mucoperiosteum is incised and elevated from the hard palate, taking care not to injure the greater palatal blood vessels exiting from their foramina in the second molar region.
- At the posterior border of the hard palate, the periosteum and soft tissues of the soft palate are incised and retracted.
- The hard palate, vomer, and atresia plate are burred down, taking care to preserve the adjacent mucosa. Care is also taken laterally not to injure the torus tubarius. The posterior bony septum should be generously removed to gain the maximum opening to compensate for postoperative scarring and contracture.
- The mucosa is then incised, and flaps are created to resurface the denuded bone.
- Soft Silastic™ tube stents are placed for 4 to 6 weeks.
- An acrylic palatal appliance fabricated from a dental cast and retained by clasps is placed and left in position for 2 to 3 weeks to support the palatal flap.
Tonsillectomy, Adenoidectomy, and Uvulopalatopharyngoplasty

Nilesh R. Vasan and K. J. Lee

Tonsillectomy and adenoidectomy are common procedures performed by otolaryngologists. Subsequently, a multitude of surgical methods have been developed that achieve the same goal. One of the most important factors leading to a satisfactory outcome is counseling of the patient or parents regarding the postoperative period, that is, pain management, otalgia, importance of continued hydration and eating, and descriptions of the appearance of the tonsillar fossa during healing. All patients must be questioned regarding bleeding, and any patient with a suspected or confirmed bleeding disorder must be investigated and evaluated by a hematologist prior to surgery.

◆ **Tonsillectomy**

◆ Following induction of general anesthesia (GA), the patient is usually intubated using a standard orotracheal tube. The procedure can be performed using a laryngeal mask; however, because of the size of the mask and tubing, the operation can be more cumbersome. Also, as the larynx is not entirely secured, this form of airway would be unwise, especially with cold dissection techniques (i.e., risk of blood aspiration).

◆ A small towel roll under the shoulder helps achieve the desired position (Rose position). A Boyle-Davis or Crowe-Davis mouth gag is then inserted. The blade length is important because too short a blade can occlude the tube and provide poor visualization. An overly long blade in a child can also cause injury to the epiglottis, risking possible epiglottitis.

◆ Inserting the mouth gag correctly requires the orotracheal tube to be centered on the tongue. This is best achieved by positioning the tube in the midline at the
tongue base. For a right-handed surgeon, using the nondominant hand, the thumb is placed on the tube against the lower incisors. The middle and ring finger retract the upper left molars to open the mouth for gag insertion. In this manner the tube should not move. The gag is inserted in a similar fashion, as one would intubate the patient. Once in place, the gag is opened, ensuring that both the upper and lower lips are not caught in the retractor.

- Excessive retraction of the gag can dislocate the temporomandibular joint, and the surgeon must be cautious of this. Following suspension of the mouth gag, the surgery may proceed. Avoid overextension of the neck, which places the teeth at risk for injury. Extra caution should be exercised in patients with cervical spine problems.

**Cold Technique**

- Some surgeons may inject the tonsillar fossa with local anesthetic (LA) with epinephrine as preemptive analgesia, as well as aiding dissection hydrostatically. A large Yankauer sucker is a prerequisite for this operation.
- A blunt instrument such as a Dennis-Brown or sponge forceps is preferable to retract the tonsil compared with an Allis forceps, which unnecessarily traumatizes the tonsil. This is important in cases where the tonsil is friable (e.g., Epstein-Barr virus tonsillitis) or where accurate pathological assessment is required (e.g., malignancy).
- The key to tonsillectomy, whichever technique is used, is getting into the correct plane. This is the potential space between the tonsillar capsule and constrictor muscle. Failure to dissect in this plane leads to tonsillar remnants as well as a more bloody operation.
- When retracting the tonsil medially, the lateral aspect of the tonsil can be seen submucosally. It is in this area within the upper pole that injection of LA is performed using an aspiration injection technique. Five minutes or so should elapse prior to tonsillectomy. The tonsil is retracted throughout the procedure.
- Using Metzenbaum/tonsillectomy scissors, the mucosa at the upper pole of the tonsil is incised. Using the lower blade of the scissors, the mucosa of the anterior pillar medially over the tonsil is divided. Using the upper blade of the scissors, the posterior pillar mucosa is divided in a similar fashion. This frees the tonsil from its mucosal attachments, which makes dissection easier.
- To obtain entry into the correct plane, the scissors are turned perpendicular to the tonsil plane and inserted just lateral to the lateral tonsillar border. The scissors are then opened, and a relatively bloodless plane should be seen. With the scissors still open within this space, the forceps is repositioned with one blade placed within this newly developed space (i.e., clasping the upper tonsillar pole).
- The tonsil is then retracted toward the lower pole of the contralateral tonsil, and in some cases considerable dissection can be performed with this move alone. When dissecting, the tonsil must be regrasped occasionally to maintain traction.
- A Gwynne-Evans or similar dissector is used to reflect the constrictor muscle off the tonsil. Care should be taken not to penetrate the constrictor muscle with the dissector. Large tears should be reapproximated with chromic suture. Dissection
should not be taken into the lingual tonsils; otherwise, troublesome hemorrhage may ensue.
◆ The lower pole can either be divided with tonsil snare or clamped and then divided with the lower pole being secured using a silk tie or suture. The tonsil fossa is packed, and the contralateral tonsillectomy is performed.
◆ Hemostasis can be achieved using 1–0 silk tie with the aid of an ear, nose, and throat (ENT) or chest Negus and a knot pusher or with bipolar diathermy. In cases with persistent arterial bleeding not controlled with diathermy, a silk tie or suture is required. Another suture used is a 2–0 plain gut with no. 863 needle. If a suture ligature is used, one must be sure that the needle is strong enough not to break and become embedded in the tonsillar fossa adjacent to the carotid artery.
◆ The nasopharynx must be suctioned following completion of the procedure to aspirate clot, which is at risk for occluding the airway in a semicomatose patient. The gag must be released and reopened to reexamine the tonsillar fossae for bleeders, which had been temporarily tamponaded by the open gag.

Hot Technique
◆ The monopolar technique using coagulation is most frequently used. An assistant who is good with removing smoke with suction aids visualization.
◆ The equipment must be checked for exposed metal, which can cause thermal injuries to the lips and buccal mucosa. Usually an insulated tip is used for this operation.
◆ The key with cautery dissection is good retraction of the tonsil, which helps avoid char and creation of false planes. With the tonsil retracted, the cautery is used to incise the tonsil mucosa anteriorly on the medial aspect of the anterior pillar. Entry into the correct plane can then be obtained using scissors as described above or with the cautery. A white tonsillar capsule in a bloodless plane signifies the correct location. Entry is best performed at the upper pole with retraction of the tonsil inferiorly and medially.
◆ If the tonsil is inadvertently entered, a new plane needs to be identified inferiorly. In cases where the plane is difficult to identify, the scissors technique described above is helpful.
◆ With the upper pole of the tonsil regrasped as described above, the tonsil is separated from the constrictor muscle. Smooth, purposeful movements using the cautery with the tonsil constantly retracted allows for easier dissection and less char formation. Following division of the mucosal pillars inferiorly along their medial borders to maintain the pharyngeal anatomy, the lower pole is then divided. Hemostasis is obtained with either monopolar or bipolar cautery. With this technique, minimal blood loss results.
◆ It is important not to overcauterize the upper pole adjacent to the uvula. This can result in an edematous and painful uvula, which impedes postoperative recovery. Good tonsillar retraction minimizes this problem.
◆ The technique of bipolar and laser tonsillectomy follows similar principles outlined above; however, laser precautions must be adhered to when using the CO₂ laser.
Key Points

◆ Over-resection of the tonsillar pillars may lead to velopharyngeal insufficiency, which is usually temporary. Stay along the medial borders of the pillars to avoid this problem as well as to maintain a normal appearance within the oropharynx.

◆ In cases of acutely inflamed tonsils (e.g., acute tonsillitis, both bacterial and viral), the tonsil can be very friable, with an increased risk of bleeding. Use of a large, blunt forceps such as a sponge forceps to clasp the tonsil avoids traumatizing the tissue further. In these cases hemostasis can be troublesome, requiring the use of silk ties/sutures for vascular control. Also, packing of the tonsillar fossae with epi-nephrine-moistened tonsillar swabs for 5 to 10 minutes may control oozing. These patients have a higher incidence of primary and secondary hemorrhage as well as being at risk for remnant tissue.

◆ Patients in whom an interval tonsillectomy is being performed following a peri-tonsillar abscess usually have considerable fibrosis. This may also be the case in patients with a history of chronic tonsillitis. A plane may be difficult to identify with the fibrotic tissue, and blunt dissection may be the safest manner in which to remove the tonsil. A Gwynne-Evans dissector may be used for this purpose. Care must be taken with monopolar cautery, which may create a plane within the fibrotic tissue and place at risk major vessels lateral to the constrictors.

◆ A good learning exercise for residents would be to perform dissection in the cadaver laboratory to familiarize themselves with the proximity of the carotid artery to the tonsils.

Complications

◆ Hemorrhage is the main potential complication and may be either primary or secondary. In minor cases of oozing, the clot can be removed with a suction or forceps and the bleeding area cauterized with silver nitrate (AgNO₃).

◆ In cases of major/life-threatening hemorrhage, the ABC (airway, breathing, circulation) principles must be observed, with removal of clot using a large bore suction and tamponade of the bleeding area using a swab secured on a sponge stick. Constant pressure must be maintained until the patient can be assessed in a controlled environment (i.e., operating room). In children, it is wise to prepare the patient for the operating room and control the bleeding under GA sooner rather than later.

◆ Adenoidectomy

◆ This operation is performed under GA. If a tonsillectomy is required, the adenoidectomy is completed first. A good headlight is mandatory.

◆ Insertion of the mouth gag is performed in the manner described above with the patient supine. The head is left in a neutral (neck not extended) position because extension of the head places the neck at risk in those patients susceptible to atlantoaxial subluxation (e.g., Down syndrome children) and risks incomplete removal of the adenoid pad.
The surgeon may undertake this operation with a laryngeal mask or endotracheal tube; however, similar drawbacks using the mask with tonsillectomy as described above may be encountered.

Assessment of the palate prior to starting the operation is mandatory. Patients with a bifid uvula or submucous cleft palate detected by palpation and Down syndrome patients are at risk for velopharyngeal insufficiency following adenoidectomy, and the surgeon may wish to abort the operation should these findings be discovered. The surgeon either preoperatively or intraoperatively should estimate the distance between the soft palate and the posterior pharyngeal wall. A “short palate” may require the surgeon not to perform the adenoidectomy.

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pack 24 to 48 hours later. The use of this pack is not common; however, in patients with persistent bleeding due to an unrecognized bleeding disorder, it may be the only method of bleeding control.

- “Hot” adenoidectomy utilizes suction cautery, which must be performed under direct vision.
- Care must be taken not to cauterize the posterior surface of the palate, which may cause nasopharyngeal stenosis secondary to formation of adhesions.
- Overly vigorous cautery of the adenoid pad places the patient at risk for Grisel's syndrome as well as eustachian tube dysfunction if the eustachian tube cushions are traumatized. Excessive curettage of the nasopharynx can also potentially cause Grisel's syndrome.
- In patients with a submucosal cleft palate or Down syndrome requiring adenoidectomy, the superior aspect of the adenoid pad can be reduced in size with suction cautery. It is important to be conservative with adenoid removal in these cases to limit the risk of postoperative velopharyngeal insufficiency. Adenoidectomy should not be performed in any child with actual or suspected velocardiofacial syndrome because these patients usually have velopharyngeal insufficiency from the outset, and adenoidectomy will make the condition worse.

Uvulopalatopharyngoplasty

Uvulopalatopharyngoplasty (UPPP) is a procedure performed for mild obstructive sleep apnea (OSA) and snoring. Most patients may have undergone sleep studies during their assessment. It is important that an anesthetist evaluate all patients prior to surgery.

- During the preoperative evaluation, a sleep nasendoscopy may be helpful. The patient is sedated in the operating room to reproduce the snoring or apnea. Under local anesthesia, a flexible nasolaryngoscope is inserted to evaluate both the palate and retrolingual space. Palatal flutter and occlusion of the oropharyngeal isthmus causing snoring/OSA is most likely to be amenable to surgical correction with UPPP. Cases of isolated retrolingual collapse causing these findings will not benefit from a UPPP.
- The operation is performed under GA, using either “hot” or “cold” techniques. Tonsillectomy is usually performed in the manner described above; however, when using the cold dissection technique, silk ties must not be used for hemostasis, as the tonsillar fossae will be obliterated by opposing the tonsillar pillars, leaving the silk ties in situ, which may risk postoperative infection. Bipolar diathermy is used instead.
- It is better to err on the conservative side, as wide resection of the palate will lead to velopharyngeal insufficiency that in some cases may be permanent with overly enthusiastic resection.
- An assessment of palatal closure against the posterior pharyngeal wall is made. Redundant mucosa can then be evaluated. It is important to remember that scar formation will cause the palate to contract, further risking velopharyngeal insufficiency.
In cold dissection cases, the palatal margin and uvula are infiltrated with 1% Xylocaine (lidocaine) with 1:100,000 epinephrine. Overinjection can distort anatomy, and caution must be taken not to inadvertently over-resect the mucosa.

The dissection starts in the midline at the uvula. Some surgeons leave a small stump of uvula to give some semblance of normal anatomy following the operation. Others remove the uvula at its base. Brisk arterial bleeding is nearly always encountered and is controlled with monopolar or bipolar diathermy.

The incision is beveled to create a flap of mucosa on the posterior aspect of the palate that can be folded anteriorly and sutured. This helps to avoid wound contracture.

Redundant posterior tonsilla pillar mucosa is excised in continuity with the palatal mucosa.

The mucosal margins are then reapproximated with interrupted 3–0 or 4–0 chromic sutures. Vicryl may be used, but the sutures tend to remain for some time. Interrupted sutures are preferable to a continuous suture because postoperative clots can be evacuated with the release of only a few sutures should this occur.

The tonsillar fossae are then obliterated by passing a suture superficially into the constrictor muscle to avoid potential clot formation.

Following observation of hemostasis in a manner similar to that following tonsillectomy, the patient should be fully awakened and extubated prior to transfer back to the recovery room. Because of physiological changes associated with OSA, these patients are at risk for respiratory failure and pulmonary edema following these procedures, necessitating overnight inpatient observation. Some surgeons/anesthetists insert a nasopharyngeal tube following surgery to maintain an airway.

UPPP is a painful operation, and the patient must be counseled on what to expect during the postoperative period, including possible increase in snoring and OSA associated with postoperative edema. Good analgesia and hydration are imperative to rapid recovery.
Palatal resection and reconstruction are most commonly performed for malignancy. Squamous cell carcinoma and minor salivary gland malignancies are the most common malignancies of the palate. Like most cancers involving the oral cavity, surgical resection is usually the treatment of choice. The use of postoperative radiotherapy is indicated in select cases (Table 9–1). Benign disease may be treated with aggressive surgical resection.

◆ Preoperative Planning

Diagnosis and staging of a palatal lesion requires a comprehensive workup, including a physical exam, radiological imaging, and tissue biopsy.

Histological Diagnosis

◆ Characterizing the histopathology of the tumor is important because it may predict the biological behavior of the tumor and impact therapy. For example, whereas squamous cell carcinoma directly invades adjacent tissue and bone, adenoid cyst carcinoma of the palate has a predilection for spreading via perineural channels. Although both neoplasms require meticulous margin assessment, the latter requires a sampling of adjacent nerves.

Imaging

◆ Once a tumor of the palate has been identified, imaging using computed tomography (CT) or magnetic resonance imaging (MRI) is helpful in determining the extent of the lesion with regard to soft tissue involvement, bony invasion, and nerve involvement.
Because hard palate lesions are commonly closely associated with the palatal bone, high-resolution CT scans represent the optimal method of imaging to assess the palatal bone for tumor invasion. MRI is useful for assessing the extent of soft tissue invasion. In malignancies such as adenoid cysts that have a propensity to spread via perineural pathways, MRI represents an effective tool to assess perineural invasion.

**Surgical Resection**

Palatal resections are performed under general anesthesia. The patient should be intubated with a flexible nasotracheal tube to facilitate exposure of the oral cavity. Exposure to the lesion and operative area is paramount to ensure an adequate resection with margins that are free of tumor. Because most palatal surgeries are performed transorally, muscle paralysis is essential. This allows placement of an appropriate retractor.

Gaining access to the palate requires appropriate retraction of the tongue, jaw, and soft tissue of the cheek. This can be accomplished using a Crowe-Davis or Dingman retractor. During placement and removal of the retractor, it is essential to secure the endotracheal tube to prevent unintentional extubation of the patient.

Once the retractor is in place and access to the oral cavity has been accomplished, a throat pack should be placed to prevent the patient from swallowing blood during the course of the procedure.

The planned resection should be delineated using a surgical marker. The margins around the tumor should be no less than 1 cm. The initial incisions can be made with either a knife or CO₂ laser. Superficial tumors that do not manifest bone erosion on preoperative imaging can be managed by raising the underlying mucoperiosteum, which serves as the deep margin. Additionally, histological examination must be performed to confirm that the tumor has not penetrated the mucoperiosteum. If tumor has penetrated the mucoperiosteum, the underlying palatal bone must be resected.

When indicated, ostectomy of the underlying bone should be made with a reciprocating saw, fine-cutting drill bit, or osteotome. Tumors that cross the midline may require resection of a portion of the nasal septum. When a tumor has eroded the palatal bone, it is essential to perform an adequate full-thickness bony resection.

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<th>Table 9–1 Indications for Postoperative Radiotherapy for Oral Cavity Carcinoma</th>
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<td>Histological evidence of angioinvasion</td>
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<td>Histologic evidence of perineural invasion</td>
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<td>Invasion of adjacent cortical bone</td>
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<td>Lymphatic metastasis (greater than N1)</td>
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Histological evidence of angioinvasion
Histologic evidence of perineural invasion
Histological evidence of lymphatic tumor emboli
Invasion of adjacent cortical bone
Lymphatic metastasis (greater than N1)
Although bony margins cannot be assessed by frozen section pathological analysis, mucosal margins can be adequately assessed. Prior to sending the pathological specimen to the pathologist for examination, the mucosal margins should be marked to identify anterior, posterior, lateral, and medial margins. This will assist a re-resection in the event that the pathologist finds a close or positive margin.

Once the resection margin has been adequately assessed and the resection has been completed, the defect should be carefully evaluated to determine the optimal method for reconstruction.

Rehabilitation of the Palatal Defect

Because the hard palate serves as the inferior floor of the sino-nasal cavity, postsurgical defects may result in an oral-nasal fistula. Failure to rehabilitate the oral-nasal fistula will result in nasal regurgitation and deficiencies in speech and swallowing.

Hard palate defects can be rehabilitated with either a prosthetic obturator or surgical flap reconstruction. Determining which technique is appropriate depends on several factors, including the biology of the tumor, the extent of the defect, and the patient’s personal preferences (Table 9–2).

Superficial defects of the hard palate can be left to granulate and re-epithelialize.

Defects entering the sinonasal cavity require a more thoughtful approach. In this situation, there are two options for palatal rehabilitation: a prosthetic palatal obturator or palatal reconstruction.

High-grade malignancies require close observation. As a result, it is recommended by most surgeons that the resection site be monitored carefully. In such cases, a removable prosthetic obturator allows for direct examination of the defect for recurrent disease.

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<th>Prosthetic obturator</th>
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<td>Advantages</td>
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Radial forearm free flap

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<td>Advantages</td>
<td>Permanent palatal restoration</td>
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<td>Appropriate for extensive defects</td>
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Table 9–2 Options for Palatal Rehabilitation
In moderate and low-grade malignancies and completely resected benign tumors, an oral-nasal defect can be reconstructed with a local palatal flap or a microvascular free flap.

**Palatal Obturator**

- Prosthetic obturation remains the gold standard for the rehabilitation of palatal defects because it is immediate and nonsurgical.
- The most significant disadvantage of a prosthetic obturator is the inconvenience and impact on quality of life. An obturator requires meticulous daily hygiene to prevent malodor and infection. Patients often complain that they are dependant on an obturator to speak or drink. In contrast, reconstruction of the defect provides a permanent closure of the oral-nasal communication but carries with it the attendant surgical risks.

**Palatal Flaps**

- The size of the defect must be carefully evaluated. Transpalatal defects that are less than one third of the hard palate may be managed with a palatal island flap, whereas defects greater than one third of the hard palate require free tissue transfer for reconstruction (Fig. 9–1A,B).
- The palatal island flap is a mucoperiosteal flap based on the palatine artery. The key is determining the amount of tissue required to resurface the palatal defect. The flap is then appropriately designed (Fig. 9–2A).
- Incisions are made and the dissection of the flap is performed in a subperiosteal plane. The flap is raised with careful attention not to injure the vascular pedicle.
- The palatal flap is then transferred into the defect and sutured to the remaining palate using absorbable suture (Fig. 9–2B).
- Hemostasis is achieved, and the operative field is copiously irrigated. The patient is placed on nasogastric feeds for 3 days, after which the patient is advanced to a soft diet over the subsequent 5 days. The patient is instructed to perform peroxide rinses 3 times a day to maintain oral hygiene and prevent infection.
- The palatal donor site will remucosalize over 4 weeks (Fig. 9–2C).

**Free Tissue Transfer**

- Free tissue transfer represents an excellent tool for permanent closure of extensive oro-nasal defects.
- Defects that are greater than one third of the hard palate area are not amenable to palatal flap reconstruction.
- The radial forearm free donor site provides a source of thin, pliable tissue that is ideal for palatal reconstruction. The flap can be fashioned to match the palatal defect, and the vascular pedicle is tunneled subcutaneously to the facial artery and vein for microvascular anastomosis.
- Postoperatively, the patient is managed similar to a pedicle flap reconstruction. Patients remain on nasogastric tube nutrition for 3 to 5 days before beginning an oral diet.
**Potential Pitfalls**

- It is essential that clear margins be obtained prior to considering a reconstruction of the palate. If there is any doubt regarding the margins, or if there is any question regarding the bone margins, primary reconstruction should be delayed. A functional reconstruction is useless in the face of persistent disease.
- Raising the palatal island flap requires meticulous dissection adjacent to the vascular pedicle. Injury to the pedicle will lead to necrosis of the palatal flap. If the vascular pedicle becomes kinked or rotation of the flap is limited, the posterior aspect of the palatine foramen can be opened using an osteotome. This will release the pedicle and increase the arc or rotation.

*Figure 9–1* Defects measuring 30% or less can usually be managed with (A) a palatal island flap, whereas larger defects may require either (B) an obturator or a free flap for reconstruction.
Figure 9–2 (A) The palatal island flap is designed to provide the appropriate tissue coverage for the primary defect. (B) The flap is then transferred to reconstruct the defect, and several weeks later (C) the flap heals while the donor site remucosalizes.
Key Points

- Prior to embarking on a palatal resection, the patient should be informed of his or her options for oral rehabilitation.
- Understanding the peripheral limits and the depth of invasion is essential in planning a resection. Preoperative CT scan will help define the tumor extent.
- Before embarking on a reconstruction, the margins should be evaluated and deemed clear of disease.
- Palatal island flap is an option for defects less than one third of the hard palate.
- The patient is fed via a nasogastric tube for 3 days, followed by an advancing diet. The palatal donor site remucosalizes over a 4-week period.
Recent medical and surgical advances, including radiology and the development of the multidisciplinary skull base team, have led to a more aggressive approach to treatment of clival lesions. A thorough knowledge of the variety of surgical approaches and their limitations is integral to the successful management of the patient with clival pathology.

◆ Surgical Approaches

The location and size of the lesion are major determinants in selecting the most efficacious surgical approach.

Transorlal Approach

◆ The clivus can be approached through the oral cavity, with or without a mandibulotomy. The decision to perform a mandibulotomy is generally based on the extent and location of the lesion. Smaller lesions can be removed without a mandibulotomy and will result in less morbidity.
◆ Good jaw mobility is needed for a transoral approach; therefore, patients with severe limitations of jaw movement may not be appropriate for this approach.
◆ Some surgeons prefer to perform a tracheostomy for all transoral approaches, whereas others advocate using an orotracheal tube and a Boyle-Davis retractor to prevent the endotracheal tube from obstructing the field of view. The decision to use an orotracheal tube or to perform a tracheostomy should be based on the possible postoperative airway edema as well as the anticipated defect size and reconstructive procedures.
To adequately expose the clivus, a palatotomy must be performed. Depending on the location of the lesion, a soft palate incision may be sufficient (for lesions in the more caudal aspects of the clivus), or excision of varying amounts of the hard palate may be necessary. Using palatal incisions, every effort should be directed toward maximizing blood supply to the “palatal mucosal flap” and minimizing cicatricial palatal shortening, which can lead to postoperative velopharyngeal insufficiency. Provided the palatal incisions heal without sequelae, the loss of varying amounts of the hard palate will result in minimal patient morbidity.

Posterior pharyngeal wall flaps are elevated to provide access to bony structures that are either involved with disease or precluding access to it. Meticulous closure of these flaps is required to provide a barrier to colonizing microbes.

Once adequate flaps have been raised, bony removal is performed to provide adequate surgical access or for tumor resection.

Following tumor removal, the defect is examined, and reconstructive options are explored. Significant dural resection generally prevents adequate primary dural seal and necessitates a graft to achieve a watertight closure.

Mandibulotomy approaches are a very effective method to obtain wide exposure of the clivus, upper cervical spine, and sphenoid sinus. Because of the postoperative edema associated with this technique, most surgeons perform a tracheostomy prior to mandibulotomy.

The procedure begins with a lip-splitting incision. This can be accomplished by extending the incision directly down the midline or in a circumferential fashion. The location of the mental nerve is noted, and the osteotomy is performed in the parasymphyseal region. Many surgeons tend to prefer a paramedian rather than a midline osteotomy because it is hypothesized that healing is superior with a paramedian osteotomy.

Because dental status can affect the bony fixation of the mandibulotomy, this should be assessed preoperatively. Edentulous patients with an atrophic mandible require a different plating strategy than dentulous patients who have a greater amount of bone. With the presently available plating techniques, nonlinear osteotomies have minimal advantages.

Depending on the area to be visualized, there are two options available for exposing the posterior pharynx:

Lesions located in the midline of the lower clivus and the craniocervical junction are ideally suited to a midline glossotomy approach. This technique provides excellent access to the clivus from the base of the sphenoid sinus to the level of C4–C6 and depends on patient factors such as the degree of jaw mobility and neck configuration. A tracheostomy is performed to minimize the risk of postoperative airway obstruction. Prior to dividing the anterior floor of the mouth and tongue, a mandibulotomy is performed as described previously. It is important to divide the tongue in the midline to avoid injury to the lingual or the hypoglossal nerves and to minimize blood loss. The incision is extended posteriorly to the epiglottis. This permits excellent exposure of the mucosa overlying the lower clivus and upper cervical spine. However, with this approach, lesions that extend superiorly into the sphenoid sinus are less well visualized, and those that extend laterally into the cavernous sinus or parasellar regions should not be approached.
by this method. Because of the difficulty in obtaining dural closure, lesions with extensive dural or intradural involvement are best exposed by other methods.

◆ For lesions extending unilaterally into the parapharynx or infratemporal fossa, an incision in the floor of the mouth will provide improved surgical exposure. The incision is extended posteriorly from the midline to the anterior tonsillar pillar on the side of the lesion. The submandibular duct and gland are preserved and left in continuity. Division of the mandibular muscular attachments allows the mandible to swing laterally. The floor of the mouth incision is then extended onto the anterior tonsillar pillar and soft palate and when retracted provides a wide exposure of the posterior pharyngeal wall and parapharyngeal space. Division of the pterygoid muscles permits access to the infratemporal fossa. This exposure provides access from the ipsilateral infratemporal fossa to the contralateral eustachian tube and medial pterygoid plate. Removal of the posterior hard palate and maxillary tuberosity provides increased exposure by opening the pterygopalatine fossa.

Transnasal/Transfacial Approach

Lateral Rhinotomy and Medial Maxillectomy

◆ An incision of the upper lip and nasolabial fold superiorly using a Z-plasty to the infrabrow region is made. An osteotomy of the nasal process of the maxilla combined with the nasal bone is performed. The medial walls of the maxilla and anterior and posterior ethmoid sinuses are removed to expose the clival region.
◆ This technique is frequently combined with a resection of the posterior aspect of the nasal septum and the face of the sphenoid sinus.
◆ Following tumor excision, a dacryocystorhinostomy and repair of the medial canthal ligament are performed.
◆ Although adequate exposure is usually possible, its limitations are visualization of the inferior and lateral extent of the tumor.

Transmaxillary/LeFort I Osteotomy

◆ A LeFort I osteotomy provides excellent exposure of neoplasms located in the upper clivus with or without lateral extension, resulting in minimal patient morbidity. The principal limiting factor is the hard palate, which makes the resection of more inferior lesions difficult and in some cases impossible.
◆ The approach is performed using gingivolabial and gingivobuccal incisions that connect the maxillary tuberosities. Miniplates are positioned prior to performing the osteotomies; the septum and lateral nasal walls are then divided. Care is taken to preserve the infraorbital nerves. Disarticulation of the maxilla from the pterygoid plates permits down-fracture of the entire maxillary infrastructure, which is pedicled on the greater palatine vessels bilaterally. A modified transoral retractor is used to provide a view of the posterior pharynx. Turbinectomies are occasionally required to increase visualization.
◆ Following tumor resection or repair of the anomaly, the maxilla is reapproximated using the previously contoured miniplates.
In more complex cases, where tumor extends laterally, superiorly, or inferiorly, a maxillotomy approach is employed. The maxilla is pedicled laterally on the cheek flap, and the osteotomies include the nasal process of the maxilla, zygoma, palate, and pterygoid plates. This allows the maxilla to be swung laterally and pedicled on its own greater palatine vessel and provides a more extensive inferior exposure, but restoration of occlusion is more complex.

The bilateral facial translocation approach is similar in concept to the extended maxillotomy but offers the advantage of a slightly greater exposure. This technique involves facial incisions with subsequent excision of the maxillary segments to provide exposure of the pterygopalatine fossa, the posterior pharynx, and the clivus. Although this approach offers better surgical exposure, it requires facial incisions and the use of large bone grafts to replace the maxillary segments.

Lateral Transfacial Approach

The lateral transfacial approach uses orbitozygomatic osteotomies to provide access to the clivus, infratemporal fossa, and pterygopalatine fossa, with exposure to the medial aspect of the contralateral nasopharynx and medial portion of the eustachian tube.

Access to the osteotomy sites is obtained using a combination of hemicoronal, preauricular, and cervical incisions. The frontal branches of the facial nerve are preserved within the temporoparietal fascia as the orbitozygomatic segments are exposed. Elevation of the temporalis muscle and fracture of the coronoid process allows access to the ipsilateral pterygoid plates, which, when removed, direct the approach to the nasopharynx. Mucosal incisions provide access to the bony cranio-cervical junction. Once the resection has been completed, the bony segments are replaced with bone grafts using miniplates.

Transethmoidal Approach

Although transethmoidal approaches to the clivus have been described, they have generally been abandoned in favor of alternative approaches.

Transsphenoid Approach

Transsphenoidal approaches are often used for removal of pituitary fossa lesions, most commonly adenomas. However, selected lesions of the upper clivus can be accessed through such an approach, and it is usually performed endonasally, but a sublabial transsphenoidal approach may also be used. This is a modification of a standard septoplasty and is therefore familiar to most otolaryngologists/head and neck surgeons. This approach is also well tolerated by the patient. The major disadvantage of this approach is the limited access to the caudal aspects of the clivus. Because the hard palate obstructs the plane of view, only the upper third of the clivus is easily accessed via this approach. This concept has been disputed by some surgeons who have reported reaching the foramen magnum using a transsphenoidal approach. Tumors that extend laterally may also present a challenge using this approach.
Transbasal Approach

- This approach is most commonly used for removal of anterior cranial base lesions. Extended transbasal approaches have been described for lesions of the clivus and craniocervical junction, and this technique generally involves a bifrontal craniotomy followed by removal of the posterior wall of the frontal sinus. Severance of the olfactory nerve fibers permits frontal lobe retraction and access to the planum sphenoidale. Removal of the planum and retraction of the frontal lobe permit access to the sphenoid sinus, clivus, C1, and odontoid peg. With a transbasal approach, the only limitation is restricted exposure of the superior tip of the clivus.

- This approach is unique because it provides access to lesions of the anterior cranial base and the clivus. Because there is less visual obstruction than using other approaches, it can also be used for lesions that extend laterally. The major challenges encountered using this approach are related to visualization of the upper clival tip and the occasional need for complex reconstruction techniques following extirpation of more extensive lesions and those requiring major dural and/or bony resection.

Endoscopic Approaches

- Numerous reports of extirpation of tumors of the anterior skull base and of the pituitary fossa have emerged, aided by the technological advances in both endoscopic equipment and image-guided systems. Basic principles of endoscopic approaches and use of image guidance are described in Chapters 2 and 3.

Neurosurgical Approaches

- Neurosurgical approaches (lateral/suboccipital, dorsolateral, and transpetrous/transtemporal) are integral to the comprehensive management of clival pathology. Interested readers should refer to the neurosurgical literature for more in-depth information.

Complications of Clival Approaches

Lingual Edema and Upper Airway Obstruction

- Lingual edema following a midline or lateral transoral approach is a common postoperative sequela. It is typically transient and minor, but in some cases it can result in varying degrees of upper airway obstruction.

- Many surgeons recommend preoperative tracheostomy because of the risk of lingual edema, especially in cases where an unobstructed view of the posterior pharyngeal wall is necessary. In select patients where a tracheostomy does not improve the operative visibility, the surgeon must be prepared to provide endotracheal intubation in the intensive care unit in the early postoperative phase (3–5 days).
Dysphagia/Aspiration

- Procedures resulting in injury to the cranial nerves involved in glossopharyngeal coordination (i.e., IX, X, and XII) can result in varying degrees of dysphagia and/or aspiration. Although prophylactic vocal cord medialization and/or gastrostomy tube placement have been advocated, many surgeons recommend post-operative assessment of swallowing and voice before further intervention is instituted.

Cerebrospinal Fluid Leak

- As the extent of dural exposure and the extent of dural resection increases, the risk of a postoperative cerebrospinal fluid (CSF) leak increases. Watertight closure and the use of vascularized tissues for repair of dural defects are necessary to prevent this complication.
- In many patients, CSF leaks will resolve spontaneously with appropriate conservative measures (elevation of the head, lumbar drainage, and avoidance of Valsalva maneuvers). However, some patients will require a lumbar drain or other operative interventions. The role of antibiotics in the prevention of intracranial infection in patients with active CSF leaks remains controversial.

Pneumocephalus

- Small amounts of intracranial air commonly occur following cranial base surgery. They are generally not clinically significant and can be managed expectantly. With the introduction of larger air volumes, increased intracranial pressure can develop, resulting in a shift of the intracranial contents with potentially catastrophic results. Introduction of air from the upper airway likely occurs during forceful expulsion (i.e., coughing or sneezing).
- Some surgeons have advocated routine tracheostomy for all patients undergoing anterior skull base resections, although an individualized approach that considers the extent of dural exposure and resection is favored by most.
- Management of tension pneumocephalus requires immediate removal of any obstructive dressings and intracranial decompression with either needle aspiration or reexploration.

Wound Infection

- Management of a simple wound infection is generally uncomplicated, by providing timely drainage of suppurative collections and the appropriate culture-directed intravenous antibiotic therapy.
- Prophylactic antibiotics are indicated in those cases where the oral or nasal cavities have been breached. Most surgeons use a combination of a broad-spectrum cephalosporin and an anaerobic pharmacologic agent.
Mandibular Malunion/Nonunion

- This complication occurs more frequently following oral cavity/oropharyngeal cancer resection than following skull base surgery. This may be due in part to the relatively low rate of significant radiotherapeutic doses to the mandibulotomy site in patients with clival pathology.
- To prevent mandibular malunion and/or nonunion, it is necessary to avoid devascularization of the bone at the osteotomy site and to provide stable rigid fixation using accepted principles of open reduction and internal fixation. With adequate bony stability, the geometric configuration of the osteotomy has little or no effect on the rate of mandibular nonunion or malunion.
- The use of mandibulomaxillary fixation has been suggested following a vertical osteotomy to minimize the forces that could contribute to bony union failure, but the efficacy of this practice remains to be established.

Temporomandibular Joint Ankylosis

- Surgical injury to the temporomandibular joint (TMJ) or long-term joint stress may cause TMJ ankylosis. Chronic TMJ pathology can result from misdirected masticatory forces due to division and/or fibrosis of the masticatory muscles or complications/sequelae of mandibulotomy. Patient symptoms can range from mild to debilitating, and a graded, individualized treatment approach is necessary. Refractory cases should be managed by individuals who have expertise in TMJ pathology.

Fistula

- Fistulization from local tissue breakdown can occur and lead to oro-cutaneous, oro-nasal, or oro-antral connections. Frequently, this is a consequence of wound infection and emphasizes the need for expedient management of infections in this patient population.
- Once fistulization has occurred, management decisions must be tailored to the site as well as to the patient. Many oro-cutaneous fistulas will heal if the wound is appropriately managed; however, oro-nasal and oro-antral fistulas can be more persistent. Many patients with small oro-nasal/oro-antral fistulas remain asymptomatic, and the effect of the fistula on the individual must also be considered. Persistent, symptomatic fistulas can be managed with obturation or surgical repair, depending on the site and size of the defect.

Serous Otitis Media/Eustachian Tube Dysfunction

- This is often unavoidable when extensive manipulation of the eustachian tube is necessary for appropriate tumor exposure and extirpation. Although many patients can be managed expectantly, some patients require long-term middle ear drainage with tympanostomy tubes for adequate symptom management.
Resection and Reconstruction of the Tongue, Floor of the Mouth, and Mandible

Daphne A. Bascom

◆ General Principles

◆ The goal of reconstruction after tumor extirpation is the restoration of cosmesis and function with minimal additional patient morbidity.
◆ Key functions of the oral cavity and mandible to consider during reconstructive planning include speech, mastication, bolus preparation, bolus manipulation, and deglutition.
◆ Functional subunits of the oral cavity and mandible
  ◇ Oral sphincter speech, mastication, and deglutition
  ◇ Alveolar ridges direct flow of saliva and collect food during mastication and bolus manipulation
  ◇ Floor of the mouth oral tongue mobility and bolus manipulation
  ◇ Oral tongue speech and bolus manipulation
  ◇ Hard palate speech and bolus manipulation
  ◇ Buccal mucosa mastication and deglutition

◆ Preoperative Evaluation

◆ General medical status: a variety of medical problems can influence the success rate of reconstruction and overall wound healing. These include diabetes, hypercholesterolemia, atherosclerosis, and previous radiation therapy. Other patient factors, such as smoking, obesity, existing coagulopathies, and hepatic disease, should also be considered because they may limit reconstructive options.
◆ Premorbid functional status
**Reconstruction of the Floor of the Mouth**

- The floor of the mouth requires mobile soft tissue. It is important to avoid scar contracture and to allow free tongue mobility. There are many options for reconstructing the floor of the mouth, and the tissue used will depend on the size and extent of the defect.
- Smaller defects may be resurfaced with a split-thickness skin graft (STSG).
  - A STSG is harvested from the lateral thigh using a dermatome at 0.015 inch thickness.
  - The graft is sutured into the oral cavity with absorbable suture and is stabilized with a bolster and/or quilting suture techniques. The STSG will survive over muscle and cancellous bone via imbibition and neovascularization.
- Regional flaps used in reconstruction of the floor of the mouth include the submental artery island flap and the deltopectoral flap.
  - The submental artery island flap skin provides thin, supple skin for anterior floor of the mouth defects. It is based on the submental branch of the facial artery. The use of this flap is dependent on maintaining an intact facial artery during the neck dissection.
  - The deltopectoral flap is an axial flap based primarily on the first four perforators of the internal mammary artery. The deltoid portion of the flap, which is the most useful for floor of the mouth defects, is a random extension of the flap. Partial flap loss, despite the delay procedure, is not uncommon.
- Free tissue transfer is used to reconstruct larger floor of the mouth defects. Fasciocutaneous free flaps are particularly useful because of the thin nature and pliability of these flaps.
  - The radial forearm free flap (RFFF) is a thin, pliable flap that has a low incidence of failure. The RFFF has minimal bulk, which facilitates tongue mobility and limits obstruction to the free movement of food during the oral phase.
  - Vascular supply: arterial supply is the radial artery. Venous outflow is two paired venae comitantes, the basilic vein and the cephalic vein.
  - Flap advantages include a long vascular pedicle, dependable vasculature, and the potential to become sensate through anastomosis of the posterior cutaneous nerve to the lingual nerve.

**Reconstruction of the Tongue**

- The tongue is one of the most difficult structures of the body to reconstruct because of its size and complex functions.
- If primary closure cannot be achieved, a skin graft can be applied with satisfactory results for small defects. Larger defects or composite defects involving a portion of
the floor of the mouth will require more bulk. A fasciocutaneous free flap, such as the RFFF, is ideal for such composite defects.

- Reconstruction of the anterior tongue: lateral arm flap, RFFF
- Reconstruction of the posterior tongue: pectoralis major free flap, latissimus dorsi free flap, rectus abdominis free flap

**Lateral Arm Flap**

- Vascular supply: posterior radial collateral artery (PRCA) and paired venae comitantes.
- A skin paddle up to $12 \times 18$ cm can be harvested, although limiting the paddle to $6 \times 8$ cm allows for primary closure of the donor site.
- Harvesting the posterior cutaneous nerve with anastomosis to the lingual nerve allows for a potentially sensate flap.
- The disadvantages of the flap are donor site appearance, hair growth at the recipient site, elbow pain, and lateral forearm numbness.

**Total Glossectomy**

- Total glossectomy defects require bulk during reconstruction. The planned reconstructive goals include (1) to direct secretions laterally toward the oropharynx and (2) to provide contact of the neotongue with the palate to assist in deglutition. A palatal drop prosthesis can be used if additional apposition of the neotongue with the palate is necessary.
- The rectus abdominis and latissimus dorsi myocutaneous free flaps are the most commonly used free flaps for total glossectomy reconstruction, although other fasciocutaneous free flaps are also used.

**Mandibular Reconstruction**

- The goal of mandibular reconstruction is to reconstitute the mandibular arch and allow for dental rehabilitation. Anterior defects result in the worst functional defects with the so-called Gump deformity. Lateral defects pose less of a functional problem.

**Reconstruction of Lateral Mandibular Defects**

- Letting the mandible “swing” is an adequate option for select patients. Mandibular drift can be minimized with postoperative isometric exercise.
- Reconstruction of the defect with a low-profile reconstruction plate and soft tissue lining over the plate with a regional, pedicled, or free flap is an option in patients with advanced disease who do not require dental restoration.
- Plate exposure is uncommon (5%) with lateral and posterior defects, up to 20% with anterior defects.
Reconstruction of Anterior Mandibular Defects

- Fibula free tissue transfer (FFTT) is the most commonly used flap for mandibular reconstruction.
  - The major blood supply is through the peroneal vessels. The artery supplies nutrients to the periosteum in a segmental fashion, allowing for the multiple osteotomies required to shape the bone.
  - Up to 25 cm of bone may be harvested safely with minimal donor morbidity.
  - The lateral cutaneous nerve of the calf supplies the skin paddle and can be anastomosed to the lingual or inferior alveolar nerve to provide a sensate flap.
  - Osseointegrated implants can be placed in the bone graft.

Iliac Crest Free Tissue Transfer

- Includes the iliac crest and internal oblique muscle.
- This flap is based on the deep circumflex iliac artery (DCIA) with its perforators supplying the skin overlying the iliac crest and an ascending branch supplying the internal oblique muscle.

  - Advantages
    - Supports dental restoration
    - Allows two-team harvest
  - Disadvantages associated with full cortex harvest (these disadvantages are minimized by harvesting inner cortex only)
    - Technically difficult to harvest
    - Significant donor site morbidity
    - Risk of hematoma
    - Long-term potential for abdominal hernia at the site of the muscle harvest

Scapula Free Tissue Transfer

- The scapular free flap is based on the circumflex scapular artery and vein.
- Between 10 and 14 cm of bone can be removed from the lateral aspect of the scapula.

  - Advantages
    - Allows harvest of adequate volume of soft tissue to support mandibular and total glossectomy reconstruction.
    - Long pedicle facilitates three-dimensional arrangement of skin paddle(s).
  - Disadvantages
    - Bone stock is thin and will not support osseointegrated dental restoration.
    - Positioning of the patient precludes a two-team approach.
    - Potential for brachial plexus injury exists due to position of patient during harvest.
Postoperative shoulder weakness and decreased range of motion: this can be minimized with early initiation of postoperative physical therapy.

**Perioperative Considerations**

- Preoperative assessment for a suitable donor site includes an Allen’s test for an RFFF and assessment of lower extremity arterial supply if a fibula free flap will be used.
- Inform the operating room and anesthesia staff regarding the site from which the flap will be harvested prior to placement of intravenous and arterial lines.
- Mark the flap site(s) in the preoperative area.
- Repeat the Allen’s test in the preoperative holding area if an RFFF will be used. Release of the ulnar artery should result in a reperfusion blush within 15 to 20 seconds. There is a 3% incidence of a positive Allen’s test in the general population.

**Intraoperative Considerations**

- A Bair hugger, sequential compressive devices (SCDs), and a rectal temperature probe should be placed at the beginning of the case.
- Tourniquet should be placed on the arm prior to prepping and draping if RFFF will be harvested.
- Sterile tourniquet on leg for fibula
- Check hematocrit at the end of tumor removal and every 4 hours thereafter.
- Maintain mean arterial pressure over 60 without pressors [blood, albumin, and Hespan® (hetastarch) are good]. If pressors are needed, request that anesthesia alert the surgical team prior to administration.
Surgery of the Parotid Gland

Richard L. Fabian

Parotidectomy for tumor resection has evolved from simple tumor enucleation with lifelong recurrences to formal en bloc gland excision with preservation of the facial nerve when possible. The formality of facial nerve identification, near total gland excision for benign tumors, and the refinement of nerve repair techniques when malignant disease does not allow nerve preservation continue to be the surgical standard for resident training and practice.

◆ Key Points

◆ Benign tumors of the parotid gland constitute nearly 95% of all parotid neoplasms in adults. Benign tumors are usually mobile, often less than 3 cm, and located in the body, tail, or posterior margin of the superficial lobe. It is also common to encounter one or more branches of the facial nerve intimately associated and stretched over the benign tumor, eliminating the possibility of wide surgical margins. There are also encounters where a high probability of lymphoproliferative or inflammatory disease does not justify an extensive procedure.

◆ Tumor recurrence, especially of benign disease, is related to tumor breech and surgical spill and not to close margin dissection.

◆ Preoperative Considerations

◆ A careful clinical history and head and neck examination should always be accompanied by a magnetic resonance imaging (MRI) study with contrast. If an unusual T2 image is encountered, consider the possibility of a vascular lesion and the need for a complementing computed tomography (CT) scan. In high probability cases angiography is the gold standard study.
◆ If metastatic disease such as melanoma is suspected, then a positron emission tomography (PET) scan provides total body assessment and facilitates preoperative planning.
◆ A slim-needle biopsy is not a recommended routine study unless the clinician suspects a primary parotid malignancy or lymphoproliferative or inflammatory disorder. Occasionally practical patient or case-driven factors, such as reluctance to accept surgery, preoperative anxiety, or medical contraindication to do surgery, will justify this study.
◆ Always assess bilateral facial nerve function prior to surgery. Document facial asymmetry in writing and with dynamic photography if a weakness is identified.
◆ The surgeon must explain the potential for a temporary or permanent facial paralysis. Corrective and technical measures to prevent and manage a paralysis should be detailed to the patient should it become a reality.
◆ The most commonly forgotten fact is that a high percentage of patients will have anesthesia over the distribution of part or all of the greater auricular nerve. It is best to refer to this as a permanent event with variable recovery.

◆ **Anesthesia and Equipment**

◆ Interaction with anesthesia is important before and after induction occurs. Endotracheal tube position should be maintained with tape fixation of the tube away from the operative side. Eye protection with tape on the contralateral side is acceptable. Eye protection on the operative side is achieved with a corneal shield.
◆ No paralytic agents are used if nerve stimulation is to be performed. This request must be voiced for each case and not assumed by the surgeon.
◆ To minimize bleeding, anesthesia is requested to keep the systolic blood pressure as low as the patient’s medical condition and risk status permit. Inadequate blood pressure control justifies case cancellation rather than suffering through constant bleeding and potential nerve injury.
◆ A preoperative instrument check should include a facial nerve simulator with variable stimulus control, a Bovie unit, a bipolar coagulator, and fine-tipped mosquito and tonsil clamps.
◆ Useful retractors include an intermediate-size periorbital retractor, a midsize Richardson retractor, and a pair of Army/Navy retractors.
◆ To facilitate parotid exposure, shoulder elevation and head extension on a thyroid bag are common. It is essential to determine preoperatively whether the patient has a history of cervical spine or disk disease. If so, thyroid bag extension is contraindicated.

◆ **Surgical Technique**

**Incision**

◆ The standard incision runs in the crease from the root of the auricle and tragus through the junction of the earlobe with the neck skin, onto the postauricular crease superior to the mastoid tip, before changing to a vertical direction.
The vertical limb of the incision lies over the posterior half of the upper sternocleidomastoid (SCM) muscle to the angle of the mandible, where it swings forward following the direction of the underlying posterior digastric muscle.

Mobile tumors less than 2 cm adjacent to the mastoid tip and upper posterior edge of the SCM may be approached through a classic face-lift incision, as long as facial nerve identification and tumor resection are not modified.

Hemostasis is potentiated by infiltration of the facial, postauricular, and upper neck skin with 1:100,000 epinephrine. All local anesthetics are avoided to eliminate the potential of drug-induced facial nerve anesthesia during dissection.

Flap necrosis is avoided by attention to the plane of dissection. Skin over the mastoid tip and posterior aspect of the flap is raised deep to the fascia overlying the mastoid tip and SCM muscle.

Anterior flap elevation is best achieved deep to the subdermal plexus on the parotid-masseteric fascia.

Two traction sutures from the anterior flap sutured to the forward drapes or attached to Kelly clamps achieve flap retraction. Ear lobule retraction requires a suture between the lobule and the drape above the helix.

Gland Mobilization (see Identification of Facial Nerve)

- From the tragal perichondrium to the tragal pointer
- From the anterior border of the SCM
- From the lateral and anterior edge of the mastoid tip
- Crossing veins from the tragus, mastoid tip, and SCM should be bipolar cauterized or tied.

The posterior facial vein is adjacent to the greater auricular nerve over the lower anterior border of the SCM. As the vein crosses the angle of the mandible, it lies immediately lateral to the lowest branches of the facial nerve.

Large externally visible deep lobe tumors compress the lateral lobe, causing atrophy of the lateral lobe, and change the angle of emergence of the facial nerve trunk from an anterior plane to a sharp lateral plane. This change of angle and more superficial location put the nerve at greater risk for transection.

Identification of the Facial Nerve

- The facial nerve emerges from the stylomastoid foramen and lies within 1 cm of the confluence of the tragal pointer, posterior belly of the digastric muscle, tympanomastoid suture line, and medial posterior aspect of the mastoid tip.
- A large crossing vessel passing under the mastoid tip lies a few millimeters lateral to the trunk of the nerve. This vessel should be isolated and tied.
- A facial nerve stimulator is set at a higher setting initially and lowered as the proximity to the nerve is narrowed.
- A wide area of gland mobilization from the tragus to the mastoid tip and anterior SCM with gentle traction on the gland will facilitate nerve exposure.
With large tumors obliterating the mastoid tip and parotid angle, the facial nerve should be approached from a peripheral branch to trunk (distal to proximal) direction. Because the midface branches have a generous peripheral cross-innervation, the author prefers these branches for this type of nerve trunk exposure.

Facial Nerve Preservation: Classic Tumor Resection

- This method of tumor resection is the gold standard for resecting tumors of the parotid gland. It is acceptable for benign tumors and required for malignant tumors of the parotid. Malignancy necessitates total gland removal.
- Tumors of the deep lobe arising from behind the main trunk or division of the upper and lower trunk with lateral lobe displacement require resection of the lateral lobe first, followed by the deep lobe.
- The classic technique is best referred to as a three-step dance:
  - Dissect along the lateral aspect of the trunk or branch of the facial nerve with a dissecting hemostat, isolating a segment of parotid tissue.
  - Stimulate the isolated gland with a nerve stimulator.
  - Bipolarize the isolated parotid tissue.
- Facial nerve branches that are stretched over the tumor are best freed with sharp scalpel dissection with minimal retraction to avoid a stretch injury to the nerve.
- Branches entering tumor are sacrificed in benign or malignant disease. This observation is uncommon in benign disease.
- Tumors involving the extreme anterior accessory parotid tissue are usually approached from a classic incision. Transoral exposure of such tumors is rarely but occasionally possible.

Facial Nerve Preservation: Modified Tumor Resection

- Conservative tumor resection is defined as limited tumor removal from the parotid gland resulting in adequate tumor resection with preservation of the gland for functional and cosmetic rehabilitation.
- As with any technique associated with parotid tumor removal, conservative resection is not acceptable for malignancy.
- Tumor penetration and spill by any method condemn the patient to a lifelong curse of recurrent disease.
- Tumor size should not exceed 3 cm. Ideal tumor locations include the anterior accessory glandular extension, pretragal area, immediate infralobular area, and posterior aspect of the lateral lobe.
- Deep lobe tumors presenting in the posterior inferior quadrant of the gland can be resected by dissecting and lifting the superficial lobe off the deep lobe, preserving the isolated facial nerve branches and resecting the tumor.
- Tumors of the superficial lobe are carefully separated from the surrounding nerve branches after identifying the trunk of the facial nerve. A facial nerve stimulator is
essential to avoid injury to a matrix of nerves and to help the surgeon delineate them from vessels, parotid tissue, and tumor.

Wound Closure

◆ Careful inspection for bleeding precedes closure.
◆ Anatomical inspection followed by formal facial nerve pes/division and branch stimulation will alert the surgeon to a possible praxic or inadvertent transection. Transection should be addressed before closure by formal nerve repair when technically possible.
◆ All surgical procedures of the parotid other than a localized biopsy require drainage. The author prefers a no. 15 French hemovac under suction with no occlusive dressings.
◆ The posterosuperior quadrant of the skin flap should be assessed for viability before and immediately after reapproximation to its proper anatomical location. A deep blue hue with poor capillary refill requires skin flap trimming back to viable tissue.
◆ A layered closure using 3–0 chromic sutures followed by a running 6–0 mild catgut chromic suture for skin closure will give excellent wound strength with minimal reaction.

◆ Postoperative Considerations

◆ Bacitracin ointment may be used for topical incision coverage. Topical sensitivity to any antibiotic ointment is characterized by increasing incision redness with no fever or other signs of postoperative infection.
◆ Drain removal relates to volume output per 8-hour shift and a diminishing output trend. Less than 20 cc per shift with a down-sloping trend heralds drain removal time. Occasionally a plateau output less than 30 cc in obese individuals is acceptable for drain removal.
◆ Postoperative pain associated with jaw motion is usually related to dissection over or under the fascia covering the masseter muscle. Occasionally a previous history of temporomandibular joint disease can be exacerbated by intubation joint stretch.
◆ The most common postoperative complaint is a blocked ear due to the intraoperative accumulation of blood and prep solution retained in the ear canal. If no history or findings of tympanic membrane perforation are noted, careful saline irrigation will solve this simple problem.
◆ Unexpected paralysis of the facial nerve not predicted by intraoperative inspection and nerve stimulation should be evaluated clinically and by formal nerve testing, with serious consideration given to early reexploration as indicated.
◆ The dreaded postparotidectomy sialocele may usually occur within the first 2 postoperative weeks. Management begins with repetitive needle aspiration of the collection, a firm occlusive dressing, and prolonged antibiotics. Failure to respond requires rehospitalization, insertion of a new drain, a pressure dressing, and intravenous fluid administration, with nothing by mouth for 5 days. In rare instances refractory cases may need radiation therapy, especially in patients with a previous history of sialectasis.
Preoperative Considerations

Before phonomicrosurgery can be performed, there must be a careful consent done, with the surgeon detailing precise goals and expectations of the procedure. The surgeon should discuss potential changes in the acoustic quality of the voice as well as the effort of phonation and capability of projection of ambient noise. These latter vocal characteristics are highly reflective of the aerodynamic efficiency of the individual’s vocal system. Ideally, the patient should undergo a full acoustic and aerodynamic assessment by a speech-language pathologist; at that time, further preoperative teaching is done. The patient is prepared for the fact that he or she will be on voice rest for 10 to 14 days if dissection is performed within the superficial lamina propria (SLP) of either vocal fold. Based on the extent of the dissection in one or both vocal folds, the period of voice rest may be longer. We have seen no difficulties with vocal-muscle atrophy or other problems related to voice rest in those patients who have had extended voice rest.

Surgical Technique

Steroids generally are not used for microlaryngoscopic procedures unless there is obvious potential airway impairment. Special care should be given to avoid the use of steroids in those patients with recurrent respiratory papillomatosis unless airway obstruction is imminent. Steroids may be used if there is suspicion that it will be a difficult exposure due to oromandibular anatomy. In this case, it is our belief that there may be less postoperative numbness of the tongue and/or taste.
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Figure 13–1 (A,B) The universal modular glottiscope. (Used with permission from Zeitels SM. Atlas of Phonosurgery and Other Endolaryngeal Procedures for Benign and Malignant Disease. San Diego, CA: Singular; 2001.)
changes from compression by the laryngoscope. This is a clinical observation that has not been proven.

- Preferably, the surgeon performs the intubation. This is an important consideration because many patients have laryngeal pathology that might be disturbed or traumatized by an imprecise intubation.

- The majority of patients are managed by means of general endotracheal anesthesia. The smallest endotracheal tube that can achieve adequate ventilation is used to allow for the greatest exposure of the laryngeal introitus. An endotracheal tube with a cuff is often used to allow for internal distension of the mesolarynx. It is not uncommon to use a Hunsaker catheter (Xomed Corporation, Jacksonville, Florida) and to employ jet ventilation in selected patients who have posterior glottic stenosis or diffuse papillomatosis. In the latter scenario, the catheter allows for a more panoramic view of the laryngeal introitus and its pathology.

- Once full paralysis is achieved, teeth guards are placed, and the laryngoscope is positioned. Phonomicrosurgical precision is best performed with the largest optimally designed examining speculum that can be admitted from the lip to the glottis.

- The patient is placed in the Jackson position with the neck flexed in relation to the chest and the head extended at the atloido-occipital joint. The laryngoscope (Fig. 13–1A,B) is maintained in position with a true suspension gallows so that the patient is in elevated-vector suspension (Fig. 13–2).

- Most surgeons use laryngoscope holders/stabilizers that treat the chest wall or a stand as a stabilizing point. Although commonplace, these devices do not employ optimal vector forces for exposure of the larynx.

- Once the laryngoscope is positioned, external counterpressure is employed at the level of cricoid cartilage, with 1 inch silk tape and a laryngeal cushion as necessary. This substantially improves anterior commissure exposure. The vector of external force on the laryngeal cartilage framework will determine the exposure of the anterior commissure, even the undersurface of it.

- The microscope is brought over, and the patient is examined under various magnifications. In the majority of cases, the procedure is performed at the highest power magnification of the surgical microscope. Given the fact that a 400 mm objective lens is typically used, the limit of the magnification is usually 10 to 13×. In most circumstances, the majority of the procedure is performed at 13×.

- As necessary, vocal-fold pathology is palpated with a blunt probe or smooth curved dissector. Surfaces such as the subcordal and subglottic regions, as well as the ventricle, may be examined by means of a rigid telescope through the laryngoscope. In the majority of cases, a subepithelial infusion is performed with sterile saline and 1:10,000 epinephrine. That solution is mixed by combining 4 cc of 1:1000 epinephrine with 36 cc of sterile saline. Throughout the procedure, it is not uncommon to use this solution on a cotton pledget as a topical vasoconstrictor.

- The subepithelial infusion is used with the majority of nodules and cysts, as well as almost all polyps, dysplastic lesions, and early cancers of the musculomembranous vocal fold. The infusion allows for distention of the normal SLP, thereby facilitating its preservation during resection.

- The majority of lesions affecting the voice arise within the SLP (nodules, cysts, polyps, etc.) or from the overlying epithelium (papillomatosis, dysplasia, cancer).
Lesions of the SLP should be resected by means of an epithelial cordotomy and subepithelial resection, with maximal preservation of the normal epithelium and normal SLP. The vocal outcome is based on the vibratory characteristics of the mucosa, which is the SLP and overlying epithelium. However, the primary oscillator is the SLP; the epithelium vibrates based on the rheological characteristics of the SLP, which it encapsulates.

Every attempt should be made to preserve the overlying epithelium when resecting polyps, nodules, and cysts so that the wound does not heal by means of secondary epithelialization, which promotes more underlying fibrosis.

When there are substantial varices and ectasias associated with phonotraumatic lesions, the 532 nm pulsed potassium titanyl phosphate (KTP) laser and the 585 nm pulsed dye laser (PDL) are extremely effective in inhibiting the lesional blood supply without creating fibrosis within the SLP. The 532 nm pulsed KTP laser is easier to use, less traumatic to the delicate mucosal layered microstructure, and more efficient than the 585 nm PDL. When using the PDL, Surgilube should be placed over the vocal fold to avoid desiccation of the overlying epithelium. These hemoglobin-sensitive angiolytic lasers should only be employed after the surgeon obtains significant experience with this technology.

When treating respiratory papillomatosis, the author typically uses the CO₂ laser or the 2 µ fiber-based thulium laser for supraglottic disease. With these lasers, which are highly absorbed by water, there is minimal functional risk in the supraglottis from thermal trauma and associated fibrosis. At the glottic level, preservation of the
superficial lamina propria is of paramount importance. For both papilloma and dysplasia, the author now exclusively uses 532 nm pulsed KTP laser, which provides a further improvement of the advantages noted using the 585 nm PDL.

When treating dysplasia of the vocal fold, the author uses the 532 nm pulsed KTP laser because it enhances a microflap epithelial biopsy from less critical phonatory regions (i.e., superior vocal fold surface). Additionally, experience has demonstrated that by treating the subepithelial microcirculation, there is substantial involution of the disease without resection. This approach enhances preservation of vocal function while inhibiting postoperative fibrosis.

The author often does one or two procedures for dysplasia in the operating room with microlaryngoscopic control, depending on the extent of the disease. It is commonplace thereafter to perform the pulsed KTP laser procedure by means of local anesthesia through a flexible laryngoscope to avoid multiple general anesthetics in the long term.

Endolaryngeal surgical treatment of vocal-fold cancer comprises a graded resection of the layered microstructure based on the depth of tissue invasion. In recent years the resection has been done with ultra-narrow margins to enhance the postresection vocal outcome.

As necessary, vocal aerodynamic incompetence associated with the resection can be treated with a combination of neocord medialization by means of stereoscopic lipoinjection and/or transcervical Gore-Tex® placement.
Carcinoma of the laryngopharyngeal complex can be treated medically or surgically; or in advanced cases, a combination of modalities may be preferable. The optimal method of therapy depends on the extent of the lesion, the presence or absence of regional metastasis, and patient preference. An appropriate workup entails a physical exam, laryngoscopy, high-resolution computed tomography (CT) scan, and a thorough discussion with the patient regarding the options for and risks associated with therapy.

**Preoperative Evaluation**

**Clinical Examination and Imaging**

- A preoperative physical exam should include a complete head and neck exam.
- In all cases, a preoperative CT scan with contrast should be performed in an effort to determine the extent of the lesion. A high-resolution CT scan provides fine sections that may be helpful in preoperative planning by discerning subtle changes consistent with tumor extension. Additionally, the preoperative scan may elucidate such findings as invasion of the prevertebral fascia, great vessels, or paraspinal muscles. These findings often render the tumor unresectable. Such cancers are best treated with nonsurgical therapy, including chemotherapy and radiation. The scan may also accurately predict cartilage invasion. Lesions that invade the thyroid or tracheal cartilages tend to respond poorly to chemotherapy and radiation, and surgical therapy should be given consideration.
Preoperative Laryngoscopy, Esophagoscopy, and Biopsy

Preoperative laryngoscopy and biopsy are used to assess the extent of the lesion, including the mobility of the laryngopharyngeal complex, vocal cord fixation, and subtle mucosal changes. Ideally, laryngoscopy and biopsy should be performed after the CT scan so that swelling and inflammation associated with the biopsy site do not complicate interpretation of the scan.

Technique

◆ Following induction of anesthesia and intubation, the patient should be positioned with a small shoulder roll placed behind the shoulders, and the head should be appropriately supported.

◆ The patient is then paralyzed with a short-acting agent to facilitate endoscopic evaluation. Ventilation should be maintained using a well-secured small orotracheally placed endotracheal tube to allow for visualization during the laryngoscopy procedure.

◆ Bimanual palpation of the neck and oral cavity should be performed, and any findings should be accurately recorded.

◆ Once the neck has been evaluated, dentition is protected with a dental guard, and the laryngoscope is carefully introduced. A systematic evaluation of the oral cavity, oropharynx, hypopharynx, and larynx is then performed. Throughout the examination, care is taken not to injure the dentition or mucosa of the upper aerodigestive tract. Bleeding and swelling will obscure the evaluation.

◆ Once the lesion has been identified and mapped, a spatula and suction should be used to assess invasion of the adjacent structures and mobility of the arytenoid cartilage. A variety of laryngoscopes may be used to assess the anterior commissure, postcricoid region, and hypopharynx.

◆ Following the laryngoscopy, a cervical esophagoscopy should be performed to assess the postcricoid region and cervical esophagus.

◆ Finally, a biopsy should be performed of the lesion and any other suspicious mucosa that demonstrates irregularity or cobblestoned appearance. Crucial areas such as the postcricoid region and the interarytenoid region should undergo biopsy to determine if conservative laryngopharyngeal surgery can be performed.

◆ Not uncommonly, pharyngeal malignancies extend in a submucosal plane. It is recommended that a superficial biopsy be followed by a deeper biopsy in the same area if submucosal extension is suspected. The deeper biopsy allows for assessment of the submucosal plane.

◆ Before waking the patient, the surgeon should draw out an accurate map of the tumor.

◆ Surgical Resection

Although a significant number of early-stage tumors of the larynx can be treated by endoscopic resection, the following is a general description of the technique for open surgery approaches to the laryngopharyngeal complex.
Successful surgery on the laryngopharynx requires an approach that affords wide exposure of the tumor but results in minimal morbidity. The most common approaches to the pharynx are the lateral pharyngotomy and the transhyoid pharyngotomy. The former provides excellent exposure to the lateral pharynx, hypopharynx, and supraglottic larynx. The latter is reserved for access to the tongue base and the posterior pharyngeal wall. Irrespective of the approach, great care must be taken to prevent injury to the sensory innervation provided by the internal branch of the superior laryngeal nerves.

**Lateral Pharyngotomy**

- Prior to the resection, a tracheotomy should be performed to provide a secure airway and allow the surgeon an unobstructed view of the lesion during the ablative surgery.
- The approach to the laryngopharyngeal complex is determined by the site and size of the tumor. Tumors involving the lateral pharyngeal wall, supraglottic larynx, or hypopharynx can be approached via a lateral pharyngotomy.
- The lateral pharyngotomy is achieved by dividing the constrictor attachments to the lateral edge of the thyroid cartilage. This maneuver will expose the pharyngeal mucosa of the piriform sinus. The mucosa can be gently reflected from the underside of the thyroid cartilage to gain access to the lateral pharynx.
- The pharyngotomy approach should be performed on the contralateral side of the tumor to ensure that the tumor is not violated unintentionally.
- Once the pharynx is open and the tumor is fully exposed, a carefully planned resection can be performed in an effort to preserve pharyngeal mucosa and sensory innervation while adequately resecting tumor.

**Transhyoid Approach**

- The transhyoid approach requires exposure of the hyoid bone. This can be approached by using electrocautery to divide the overlying fascia. Once the hyoid is identified, the supraglottic muscles should be transected using electrocautery.
- Following division of the supraglottic muscles, the mucosa of the vallecula should be entered with a no. 11 blade, which provides a clean incision into the anterior pharynx.
- Once the pharynx is opened, Metzenbaum scissors can be used to open the pharyngeal mucosa laterally. Great care must be taken to prevent injury to the internal branch of the superior laryngeal nerve.
- The hyoid can then be retracted inferiorly while a retractor is placed on the base of the tongue superiorly to gain wide access to the posterior pharyngeal wall.

**Tumor Resection**

Tumor extension is a function of several factors, including the inherent biology of the tumor and the anatomical site of the tumor. Tumors that arise in areas that are rich in blood supply and lymphatic drainage, such as the pharynx, hypopharynx, and supraglottic larynx, are more likely to present with regional metastasis. Additionally,
these tumors require aggressive margins to encompass tumor emboli and submucosal spread. However, tumors that arise from the glottic larynx where the lymphatic network is limited are less inclined to present with regional metastasis and submucosal spread. As a result, tumors derived from the glottic larynx can be safely resected with a smaller margin.

- Tumors deriving from the pharynx, hypopharynx, and supraglottic larynx require wide margins (1–2 cm) and careful intraoperative assessment. Because these regions are high in vascularity and lymphatic drainage, all margins must be assessed for tumor in transit.
- Tumors arising from the glottic larynx will tolerate a narrow margin (2–3 mm).
- Tumor resection should be accomplished with a scalpel to ensure precise and accurate incisions. Electrocautery may distort tissues and complicate margin assessment.
- The margins of the resection specimen should be oriented and marked to facilitate communication between the pathologist and the surgeon.
- Preservation of mucosa deserves special attention because it cannot be overemphasized that the postoperative function will largely depend on the patient’s ability to sense saliva and food and protect the airway. Every effort should be made to preserve disease-free mucosa and sensory innervation.
- Only after the pathologist has confirmed that the tumor has been adequately resected can the reconstruction be considered and undertaken.

**Conservation Laryngectomy**

- The term *conservation laryngectomy* refers to resection of a portion of the cancerous larynx with the intention of preserving voice and swallowing postoperatively. Conservation laryngeal surgery is contraindicated in patients who have been previously radiated, tumors that involve the interarytenoid space, and tumors that require resection of both arytenoids.
- *Vertical laryngectomy* refers to a vertical hemilaryngectomy most commonly performed for tumors involving the hemilarynx. Relative contraindications include tumors that involve the supraglottic larynx, cricoid cartilage, or tumors with cartilage invasion. The compartmentalization of the larynx tends to sequester tumor growth and prevent early glottic lesions from spreading to the contralateral side. Although compartmentalization of the glottic larynx prevents lateral spread of early glottic lesions, supraglottic cancers can spread to the contralateral supraglottis. As a result, tumors involving this area can spread submucosally and require complete supraglottic resection even when the lesion is limited to one half of the supraglottic larynx. However, the supraglottis is compartmentalized from the glottic larynx. As a result, early supraglottic tumors tend not to invade the glottic larynx, making them amenable to a supraglottic resection.
- *Supraglottic laryngectomy* refers to a horizontal resection of the larynx above the true vocal cords. This procedure is contraindicated in tumors that extend inferiorly to the true vocal cords. Because of the rich lymphatic network associated with the supraglottic larynx, neck dissections are often indicated during the treatment of these tumors.
Both vertical and horizontal conservation laryngectomies can be reconstructed in a single-stage closure using the adjacent tissue. During the healing process, patients receive nutrition through nasogastric tube feeding, and their airway should be maintained with a cuffed tracheostomy tube for 7 days to prevent disruption of the reconstruction.

Reconstruction of the Larynx

Reconstruction of the laryngeal defect is best accomplished using native tissue; however, not uncommonly, extensive defects require the transfer of tissue from elsewhere in the body. The options include local flaps, regional flaps, and free flaps. The method of reconstruction depends on the size of the defect, the involvement of other structures such as the cartilage framework, and the patient's history of radiation therapy. Irrespective of the method of reconstruction, the surgical principles are unchanged.

Whenever possible, reconstruction of the larynx or pharynx should be accomplished with “like tissue.” Thin, pliable, and innervated tissue offers the optimal form of reconstruction.

If the defect of the upper aerodigestive tract cannot be closed primarily by rotating adjacent tissue, and the patient has not been exposed to external beam irradiation, local skin flaps can be raised and rotated to reconstruct defects of the hemilarynx.

Reconstruction of the hemilarynx using adjacent skin flaps is accomplished by first raising adjacent cervical skin flaps. The skin flaps are raised in a plane deep to the platysma in an effort to preserve blood supply.

The skin flap is then rotated down into the defect and sutured to the cut edge of the native mucosa of the remaining larynx. This creates a laryngostome that is left to heal for 2 to 3 weeks.

During the postoperative period, it is essential to carefully maintain the airway. Immediately postoperatively, a cuffed tracheostomy tube should be safely secured and maintained with an inflated cuff. This will prevent air from being shunted up through the healing laryngeal reconstruction. After 5 days, the cuffed tube may be changed to a metal uncuffed tube; however, the patient should be monitored closely for the development of subcutaneous emphysema, indicating that a cuffed tube should be replaced until further healing has occurred.

The second stage of this two-stage procedure involves releasing the skin flaps and closing the laryngostome.

If the patient has been previously treated with radiation therapy, local flaps are ill advised because the blood supply to the adjacent skin is often compromised. In such cases, the use of free tissue transfer is best suited because the thin, pliable skin characteristic of the radial forearm free flap provides “like tissue.”

Reconstruction of the Pharynx

Reconstruction of the pharyngeal defect can be accomplished with regional flaps, such as the pectoralis myocutaneous flap or free flaps. The optimal choice for reconstructive method is often dependent on the extent of the defect. Although
noncircumferential defects of the pharynx can be managed appropriately with a pectoralis flap, circumferential defects require reconstruction with a flap that can be tubed. Free flaps, such as the jejunum, radial forearm, and anterolateral thigh, are best suited for these defects.

Pectoralis Myocutaneous Flap

◆ The pectoralis flap is best suited for “patch” defects of the pharynx. The pectoralis flaps should be designed with a skin paddle that will adequately reline the pharynx.
◆ The myocutaneous flap is raised and tunneled under the intervening neck skin.
◆ The skin paddle is then sutured to the cut edges of the pharyngeal mucosa. It is imperative that the skin paddle and the native mucosa be closed using absorbable suture and in a technique that facilitates opposing raw edge to raw edge (i.e., vertical mattress sutures).
◆ Once the defect is closed and the continuity of the pharynx has been reestablished, the patient is allowed to heal for 7 to 10 days unless he or she has been previously treated with radiation, in which case the patient is allowed to heal for 14 days prior to feeding. During the postoperative period, the patient should be fed through a nasogastric tube or a gastrostomy tube. Patients who have been previously radiated often require an extended period for healing. This group of patients is often best served with a gastrostomy tube for postoperative nutrition.

◆ Key Points

◆ A thorough preoperative workup, including physical exam, diagnostic laryngoscopy, and biopsy, as well as imaging, is essential in the therapeutic decision-making process.
◆ The optimal method of therapy depends on the extent of the lesion, the involvement of adjacent structures, and the patient’s goals.
◆ Surgical approaches to the larynx and the pharynx should be chosen appropriately to provide adequate exposure yet minimal morbidity.
◆ Adequate resection margins are imperative and should be confirmed with frozen section pathology prior to embarking on the reconstruction.
◆ The method of reconstruction should be carefully thought out to provide “like tissue” in an effort to achieve the best functional results.
Effective voice restoration is essential for the rehabilitation of individuals undergoing total laryngectomy. Three methods are available: the electrolarynx, esophageal speech, and tracheoesophageal (TE) speech. Historically, esophageal speech is the method by which all others are compared. In this method air is injected into the cervical esophagus and immediately expelled, causing the vibration of the opposing mucosal surfaces of the pharyngoesophagus, which is then articulated into speech. This method is very difficult to learn. The electrolarynx is the most common and the easiest method to learn. However, many patients do not like the unnatural, mechanical sound of voice produced. TE voice restoration is currently the preferred method of postlaryngectomy speech.

**Secondary Tracheoesophageal Puncture**

**Patient Selection and Timing**

- There are no absolute contraindications to secondary tracheoesophageal puncture (TEP). Specifically, radiation therapy is not a contraindication.
- Relative contraindications include the patient's inability to use and care for the prosthesis due to impaired mental status or decrease in manual dexterity, bilateral severe sensorineural hearing loss (patient cannot hear the TE voice), and limited pulmonary function (restricts the fluency and volume of speech). The introduction of the indwelling prosthesis and the hands-free valve has eliminated many of the relative contraindications.
- TEP is performed 4 to 6 weeks following total laryngectomy, 6 to 8 weeks following postoperative radiation therapy or until the peristomal skin has recovered from
radiation toxicity, and at least 4 weeks following recovery from reconstruction of a total laryngopharyngectomy or total laryngopharyngoesophagectomy defect and adjunctive therapies.

Preoperative Evaluation

◆ Transnasal esophageal insufflation testing is performed to assess the pharyngeal constrictor muscle response to esophageal distention. Insufflation testing is also done after flap reconstruction or gastric pull-up to determine the quality of voice.

◆ When hypertonic or spastic speech is present, a secondary pharyngeal constrictor myotomy (PCM) or the injection of Botox (botulinum toxin A) into the pharyngeal constrictor muscles is performed; the latter is the preferred method. The secondary PCM is done at the same time as the puncture and stomaplasty if indicated.

◆ Barium swallow: the stoma is marked radiographically, and the proposed puncture site is determined in relationship to the pharyngoesophageal segment. This is particularly useful following flap reconstruction. Esophageal stricture can also be identified.

◆ Stoma size must be at least 2 cm to allow prosthesis placement and to avoid airway compromise.
  ◦ Microstomia is treated with serial dilatation using silicone laryngectomy tubes (recommended for irradiated patients) or stomaplasty.
  ◦ Stomaplasty is performed prior to TEP, leaving the posterior wall intact during the same operation.

Surgical Technique

◆ An endoscopic puncture is made through the TE party wall through which a one-way silicone valve is placed. This tubular prosthesis maintains the puncture site, protects the airway from aspiration of saliva and foods, and allows pulmonary air to be directed across the pharyngoesophageal mucosa for voice production (Fig. 15–1).

◆ The classic technique described below has been modified by many clinicians over the years to include the use of local anesthesia, transnasal esophagoscopy, and the potassium titanyl phosphate (KTP) laser, among other methods. Patient selection regarding the method used and the type of anesthesia is critical to success. Challenging patients commonly require general anesthesia.

◆ The Blom-Singer tracheostoma puncture kit (InHealth Technologies, Carpinteria, California) is available for use and includes all necessary items.

◆ The procedure described below requires general anesthesia and is usually performed in less than 30 minutes.

◆ Esophagoscopy is first performed to evaluate the esophageal mucosa for disease and the patency of the lumen.

◆ Following esophagoscopy, the esophagoscope (surgeon’s choice) is withdrawn to the level of the stoma, with the bevel positioned against the posterior wall of the trachea so that the light can be seen and the bevel palpated. This also protects the pharyngeal wall from penetration by the needle, thereby preventing the risk of epidural abscess.
It is imperative that the puncture is full thickness through the party wall to prevent mediastinal dissection with the catheter and resulting mediastinitis.

A 14-gauge sheathed catheter is introduced into the bevel of the esophagoscope ~5 mm below the mucocutaneous junction of the stoma. The needle is withdrawn, leaving the sheath in place.

A wire on a tapered catheter is threaded through the sheath into the esophagoscope, then it is grasped and pulled out of the mouth of the scope. The wire is cut from the end of the catheter, which is then directed down the scope into the esophagus.

The catheter is secured into place at the stoma and can be used for feeds if necessary.

The Blom-Singer kit can be replaced by using a curved 18-gauge needle, 24-gauge wire, 14-gauge red rubber catheter, no. 11 or no. 15 scalpel blade, and hemostat. The curved 18-gauge needle is inserted through the party wall as described above. The 24-gauge wire is inserted through the lumen of the needle, and the needle is removed. The scalpel is used to make a stab incision immediately adjacent to the needle, and the hemostat is used to enlarge the opening. The proximal end of the wire is then secured to the tip of the red rubber catheter. The wire and attached catheter are pulled through the party wall, up the esophagoscope, and out of the mouth. It is then directed into the esophagus.
If a stricture is present, one may use a pediatric scope and/or perform esophageal dilatation prior to TEP.

If it is impossible to use a rigid esophagoscope due to stricture or neck fibrosis, a flexible esophagoscope or a fenestrated endotracheal tube (ETT) in lieu of an esophagoscope and a flexible bronchoscope to illuminate the puncture site can be used.

An appropriate-size ETT is chosen to pass through the esophageal lumen.

A window 7.4 to 10.0 mm in size is cut at the junction of the middle and distal third of the ETT.

A flexible bronchoscope passed inside the lumen of the ETT allows for a concomitant esophagoscopy. Light from the bronchoscope illuminates the puncture site.

An Intracath (The Deseret Company, Sandy, Utah) venous needle with an attached catheter is directed through the posterior tracheal wall into the lumen of the ETT. If necessary, forceps are used to grasp the catheter and pull it through the mouth. A red rubber catheter is then sutured to the catheter and delivered through the TEP site.

The prosthesis is generally placed 48 hours following secondary TEP, but it can be placed immediately. Voicing can begin immediately, provided that a secondary myotomy is not performed.

**Primary Voice Restoration**

Primary TEP results in the development of successful tracheoesophageal speech in 50 to 93% of patients. It eliminates the need for additional anesthesia and decreases the risk of mediastinal dissection and posterior esophageal perforation compared with secondary TEP. Despite an overall excellent success rate, primary TEP is not performed by some clinicians, based on lack of experience and fear of complications. Tracheoesophageal puncture is rarely done as a secondary procedure likely because of patient bias toward the initial form of speech and reluctance to undergo another surgical procedure.

**Patient Selection (see Secondary Tracheoesophageal Puncture)**

The only absolute contraindication is separation of the party wall.

Primary TEP can be performed in undecided patients and allowed to close if the patient does not wish TE speech post operatively.

**Surgical Technique**

This technique includes five steps that are done in an ordered sequence: incision (laryngectomy), tracheostoma construction, TEP, unilateral PCM or pharyngeal plexus neurectomy (PPN), and buttressing the TE party wall.

If the trachea is smaller than 3 cm, a stomaplasty is performed.

The TEP is then performed using a ruler, right-angled clamp, and no. 15 scalpel blade.

The puncture is made 1.0 to 1.5 cm from the posterior cut edge of the stoma.
A right-angled hemostat is placed in the esophagus through the pharyngotomy and is pushed against the posterior tracheal wall.

A 4 mm horizontal incision is made over the tip of the hemostat, and the hemostat is pushed into the tracheal lumen.

The jaws of the hemostat are opened, and a no. 16 French Silastic® Foley catheter is grasped and pulled through the party wall and fed down into the esophagus.

The catheter is sewn to the superior skin flap after the skin is closed and can be used to feed the patient in the immediate postoperative period. Alternatively, the prosthesis can be primarily placed and the patient fed through a nasogastric tube.

PCM or PPN is always performed to prevent spasm.

The constrictor muscles are cut vertically in the posterior midline when performing a PCM.

The PCM must be complete to the level of the mucosa and extend from the level of the TEP to the tongue base to be successful.

The PPN can be used as an alternative to PCM or when the PCM is inadvertently omitted and the pharynx is closed.

If a flap is used, the segment of muscle from the puncture site to the inferior flap is myotomized.

Buttressing the TE party wall

The party wall usually separates ~3 to 5 mm above the puncture site and is therefore buttressed using interrupted sutures of 3–0 chromic or 4–0 Vicryl to obliterate this space. This helps to maintain the integrity of the posterior stoma and prevents the collection of saliva in this area if a fistula develops.

If separation of the party wall extends below the area of the planned puncture, the puncture is delayed. This can lead to pocket formation with abscess and loss of the posterior tracheal wall.

Postoperative Care

The voice prosthesis can be placed anytime after the patient has begun to take peroral feeds; the catheter in the puncture site is used to feed the patient until that time.

Voicing, however, is delayed until 10–14 days postoperatively to allow the hypopharyngeal closure to heal.

If the patient is discharged from the hospital with the Foley catheter in place, the balloon is filled with 2 cc of normal saline to prevent accidental dislodgment of the catheter from the puncture site. The patient is also given assorted sizes of red rubber catheters and instructed on how to replace the catheter if it becomes dislodged.

Voicing may become interrupted during postoperative radiation therapy due to mucositis or the patient’s inability to occlude the stoma due to pain. The prosthesis may remain in place during this time, although not used.
Complications

- The most common complications encountered following primary and secondary TEP include loss of the puncture site by dislodgment of the catheter placed at the time of puncture or partial or complete extrusion of the prosthesis, migration of the puncture site, formation of granulation tissue, aspiration of the prosthesis, cellulites, stomal stenosis, and pharyngoesophageal stenosis.
- Violation of the posterior esophageal wall, passage of the catheter through a false passage, and esophageal perforation are unique to secondary TEP and can result in epidural abscess, vertebral osteomyelitis, and mediastinitis.
- Stricture dilatation has been associated with an increase in complication rate in secondary TEP.
- Previous radiation, diabetes mellitus, chronic obstructive pulmonary disease, alcoholism, and extended laryngectomy have not been found to be significant risk factors for complications.
Tracheostomy

Nilesh R. Vasan and K. J. Lee

◆ Preoperative Considerations

◆ Pediatric tracheotomies pose special considerations because of differences in anatomy and physiology. Subsequently, the evaluation, surgical technique, and postoperative management for pediatric patients are different compared with adults, and these points will be highlighted. A cricothyroidotomy is to be avoided in infants due to poor landmarks and a higher risk of subglottic stenosis.

◆ The procedure can be performed under general or local anesthesia. Performing this operation under general anesthesia in an operating room, with the airway secured via orotracheal intubation, is the most common and safest technique.

◆ Patients with impending airway compromise require the procedure performed under local anesthesia. In these patients, a general anesthetic would lead to collapse of the upper aerodigestive tract musculature, which the patient is actively using to maintain the airway.

◆ The following should be available: a good headlight and an open tracheostomy instrument tray that includes tracheal dilators, suction, retractors, and a cricoid hook. In pediatric patients, a wide selection of tracheostomy tubes and pediatric bronchoscopes should also be available. The airway can be secured with a ventilating bronchoscope, and a tracheostomy in children can be performed with the bronchoscope in place.

◆ Surgical Technique

◆ The patient is positioned with the neck extended using a shoulder roll. In the majority of patients, a vertical incision 1.5 to 2.0 cm between the cricoid cartilage
and suprasternal notch will suffice. This is especially important in emergent situations, as well as in infants where the soft laryngeal cartilage landmarks may not be palpable. With this incision, the wound can be easily extended superiorly or inferiorly to the appropriate level. In young adults, a small transverse incision may result in a more aesthetic scar.

- In elective cases, the operative site is injected with 1 to 2% Xylocaine (lidocaine) with 1:100,000 epinephrine 5 to 10 minutes prior to incision. Aspiration prior to injection will avoid inadvertent intravascular infusion of epinephrine and assist in airway localization.

- With the vertical incision, the surgeon and assistant elevate either side of the wound with retractors. This allows for easier dissection of planes and identification of structures using the Bovie blade on coagulation mode (the cutting mode predisposes to bleeding).

- It is important to remain in the midline; the surgeon also must be cognizant of excessive retraction by the assistant, which may skew the dissection off center and place the recurrent laryngeal nerve (RLN) and vessels at risk. Dissection within the midline is relatively bloodless. The risk of subcutaneous emphysema can be reduced by avoiding unnecessary dissection off center and by ensuring that skin around the incision is not closed too tightly around the tracheostomy tube.

- The thyroid isthmus should be divided if it directly overlies the trachea at the desired level of entry. The isthmus should be clamped and divided, and the stumps should be secured with a “purse string” or “stick tie” suture ligation. Some surgeons divide the isthmus with the Bovie blade using bipolar electrocautery for further hemostasis. Retracting the isthmus to access the trachea may cause difficulty in recannulating the patient due to the isthmus blocking tube reinsertion should the tube be accidentally removed in the early postoperative period.

- Entry into the trachea is performed at the second ring. A high tracheostomy will result in subglottic stenosis.

- In cases where an urgent tracheostomy is required due to laryngeal cancer, a reasonably high tracheostomy is made if oncologically feasible. This will allow an adequate tumor-free margin below the tracheostomy site when a total laryngectomy is performed.

- In infants, care must be taken not to dissect into the root of the neck. Overextension of the neck in infants raises mediastinal structures such as fat and thymus gland into the operative field, making dissection more difficult. The surgeon must be aware of the relatively cephalad position of vessels in these necks, which are at risk for injury.

- Entry into the trachea can be performed using several methods. In adults, a window of cartilage is excised usually at the second or third ring with an inferior midline cut to allow tube entry. Others prefer an inferiorly based Bjork flap. When time is of the essence, after the initial cartilaginous incision is made, a Gruenwald nasal forceps can be used to excise the cartilage. Care should be taken not to dislodge free cartilage into the trachea. This can be avoided by grasping the segment of cartilage to be removed with a hemostat. Prior to tracheal entry, the surgeon should inform the anesthetist and change the suction to a Fraser sucker to allow better clearance of secretions from within the tracheal lumen. Withholding ventilation at the time of tracheal incision will avoid blood splatter.
In infants, a vertical incision is made into the trachea, as other forms of entry lead to tracheal collapse and place the child at risk for tracheal stenosis. The incision should be made from an inferior to superior direction to avoid possible injury to root of neck structures. Stay sutures should be placed on either side of a vertical incision in infants, encompassing the second and/or third ring, to retract open the tracheostomy site; 2.0 Prolene is ideal and can be taped to the child’s chest at the end of the procedure. In adults, a stay suture can also be used to retract the inferiorly based Bjork flap. In both cases, the sutures allow easier reintroduction of a tracheotomy tube during the initial change of tracheostomy tube or in the event of inadvertent dislodgment of the tube.

Prior to incising the trachea; the surgeon must check tube integrity and functionality and availability of new anesthetic tubing for the tracheostomy tube should this be required. The anesthetist is then instructed to retract the endotracheal tube to just above the tracheostomy site. In this way, the airway can be easily restored should there be difficulty with tracheostomy tube insertion.

Following insertion of the tracheostomy, the surgeon must ensure that the tube tip is not in contact with either the anterior or posterior tracheal wall, as this may lead to tracheal obstruction as well as erosion. Also, if the tube length is too short, it will be placed high and be at risk for dislodgment. Conversely, a long tube or a low tracheostomy may lead to placement of the tracheostomy into the bronchus. Only after both the surgeon and the anesthetist are satisfied that the tube is in the correct position is the endotracheal tube removed.

In all cases the tube must not be forced into the trachea, as this may cause a posterior tracheal wall tear and place the patient at risk for pneumomediastinum and tracheoesophageal fistula. Should this occur, the tracheostomy tube is removed, the tracheotomy incision is extended, and the posterior tracheal wall tear is repaired. The patient is intermittently ventilated with the endotracheal tube, which should have been left in place.

In infants and children especially, the surgeon must determine if the tube is correctly positioned without impingement of the tube tip against the anterior tracheal wall. This can place the patient at risk for tube obstruction and possibly creation of a tracheoinnominate fistula.

Prior to wound closure, hemostasis is secured, and the tracheostomy tube is sutured to the skin. Care must be taken not to close the skin around the tube too tightly, as this may lead to surgical emphysema or pneumomediastinum. Bulky dressings placed under the tracheostomy tube flange should be avoided to prevent accidental decannulation. A thin piece of Telfa® can be placed between the tube and the incision. Following formation of a tracheocutaneous tract 48 to 72 hours after surgery, a dressing may be placed beneath the flange to reduce the risk of granulation tissue formation for those patients who will require a long-term tracheostomy tube. In all cases, the staff caring for these patients should be trained appropriately in tracheostomy care.

The tube is then secured using a Velcro® tracheostomy collar with the neck slightly flexed. The collar is secured, allowing one finger under the collar. If the collar is tied when the neck is extended, it will become loose when the patient flexes his or her head, risking decannulation in the event that the tube is not sutured in place. If a neck tie is to be used, it must be secured with a tight square knot and not a bow, which can become untied easily.
When the procedure is performed under local anesthesia, the surgeon must allay the patient’s fear with constant reassurance. Prior to entry into the trachea, the anterior tracheal wall is infiltrated with local anesthetic. Alternatively, topical lidocaine may be instilled in the trachea upon entry into the airway. The patient is informed that he or she will cough and lose the ability to speak. Once the tube is inserted, a general anesthetic can be administered should the airway require further evaluation.

In infants and obese patients, defatting the tracheostomy site allows the skin to approximate the trachea, which will diminish the risk of accidental decannulation. Obese patients may require special tubes of extended lengths and adjustable flanges (Portex tubes). This should be anticipated preoperatively and made available at the time of surgery.

Special Considerations

Percutaneous Tracheostomy

This form of tracheostomy is ideal for patients in the intensive care unit setting where the patients are orotracheally intubated and ventilated, and therefore less readily mobile. A variety of percutaneous tracheostomy sets are available.

The basic principle involves insertion of a trochar through the skin and into the trachea, followed by serial dilatation of the trachea using progressively larger diameter dilators until a tracheostomy tube can be inserted.

An assistant operating a flexible fiberoptic scope inserted through the endotracheal tube can confirm entry into the trachea and level of entry. In this manner a false passage is avoided, and the placement of the tube can be checked. An attachment that allows simultaneous insertion of the endoscope while ventilating the patient is available.

Patients with No Normal Surgical Landmarks

This situation usually is encountered in those patients with advanced cancer in the neck whereby a tracheostomy is a palliative procedure. In patients with previous radiotherapy, the neck can also become very fibrotic, precluding identification of surgical landmarks.

In these cases, insertion of a 23-gauge needle with a syringe to aspirate air will allow the surgeon to localize the larynx/trachea.

A vertical incision is mandatory in these cases.

Emergent Tracheostomy

In this dire situation, there is impending airway obstruction or the airway is obstructed.

Depending on facilities and location, a cricothyroidotomy may be the best option for initial airway control.
If a tracheostomy is performed, the following steps should be noted:

- The patient must be supine.
- With the nondominant hand, the medial aspect of the hand thrusts/extends the neck with pressure on the inferior aspect of the mandible. The thumb and index finger of the nondominant hand clasp both sides of the larynx for stability.
- With the dominant hand, a vertical incision is made down to the trachea using a scalpel or coagulation diathermy. There may be bleeding from the anterior neck vessels and thyroid; however, once entry into the trachea has been obtained, the bleeding can be dealt with after the airway has been secured.
- It is imperative to move swiftly, and a tracheostomy can be performed in this manner within seconds.

Postoperative Care

- Ideally, the tracheostomy tube should not be changed before 48 to 72 hours, after which time a “tract” forms and the risk of creating a false passage is reduced.
- Instruments required for the initial tube change include a good headlight, suction, a cricoid hook, a tracheal dilator, and the help of an assistant.
- In a partially dislodged tracheostomy tube, the end of the tube may be abutting against soft tissue, closing off the lumen and placing the patient in respiratory distress. In this situation, the tube should be removed and the tracheostomy opening secured with a hook. The tracheostomy wound is kept open with the tracheal dilator until the tube is reinserted.
- In a normal person, the nasal cavity allows the inspired air to be warmed, humidified, and filtered. A tracheostomy bypasses this area and exposes the lower respiratory tract to dry cold air. As a physiological reaction to this, the lower respiratory airway hypersecretes mucus until the mucosa becomes accustomed to its new environment. Excessive secretions may cause potentially life-threatening airway obstruction. In the early postoperative period, these patients require frequent suctioning and humidification with warm air.
Laryngeal Framework Surgery (Laryngoplastic Phonosurgery)

Steven M. Zeitels

Laryngeal framework surgery is typically performed for aerodynamic glottal incompetence that has resulted in dysphonia. Most commonly, it is done for vocal-fold paralysis or paresis. It may also be done for tissue loss from trauma or cancer resection. Neurological disorders can also be treated by laryngeal framework surgery, as can generalized vocal-fold atrophy.

◆ Preoperative Considerations

◆ During the office evaluation, laryngeal stroboscopy is imperative for an accurate assessment of a variety of factors contributing to the dysphonia. Transoral telescopic stroboscopy is optimal for assessing the details of the anatomy and generalized pattern of glottal closure and vibration. Flexible fiberoptic stroboscopy provides for observing configurations of paralysis-induced compensation of the laryngeal and pharyngeal musculature because the tongue is not extruded.

◆ The vocal fold with impaired mobility must be assessed for its position in the axial and vertical planes, as well as magnitude of denervation-related flaccidity. Care should also be taken to assess the glottis for mucosal lesions and surface pliability that may be related to routine phonotrauma. It is also very important to assess the range of motion of the contralateral arytenoid, especially with regard to its limits of abduction. This is critical information if one is to consider an arytenoid repositioning procedure.

◆ Surgical Technique

◆ A Medrol (methylpredisolone) dose pack is started a day prior to surgery. Administration of steroids is especially helpful in minimizing intraoperative edema,
which can alter judgments regarding the shape and size of the implant. It is also important for restricting intraoperative and postoperative airway edema. Typically, the patient will be discharged on the first postoperative day and will complete the Medrol dose pack after discharge.

When the patient reaches the operating room, the nasal membranes are locally anesthetized with a decongestant using a combination solution or cocaine hydrochloride. A sterile flexible fiberoptic laryngoscope is then used to check the anatomy and the glottal function prior to injecting local anesthesia. During the procedure, it is prudent to employ a nasal cannula with oxygen, especially in elderly patients with cardiopulmonary dysfunction. Although many surgeons separate the field of the nasal chamber and oral cavity from the neck incision, this author found that to be unnecessary and typically places the towels over the eyes but leaves the nose, mouth, and neck exposed together.

Laryngoplastic phonosurgery is typically performed under local anesthesia with monitored intravenous sedation. In selected circumstances, it is done with general endotracheal anesthesia; however, this approach precludes real-time adjustment of the reconstruction based on feedback in the acoustical quality of the voice.

Intravenous perioperative antibiotics are used routinely, and 10 to 15 mg of dexamethasone is administered directly after the intravenous line is placed preoperatively.

A natural neck crease is selected for the incision at the approximate level of the lower edge of the thyroid lamina (Fig. 17–1). Local anesthesia is a critical component to effective laryngoplastic phonosurgery. We employ a solution that comprises equal parts Marcaine (bupivacaine hydrochloride) 0.75% with 1:200,000 epinephrine and 2% lidocaine with 1:100,000 epinephrine. The resultant solution is 0.375% Marcaine, 1% lidocaine, and 1:150,000 epinephrine. A total of 50 cc is usually mixed for potential use during the case. Typically, 25 to 30 cc is used. The dermis is injected along the selected crease. Local anesthesia is also placed in the subplatysmal plane and along the ipsilateral thyroid lamina. If an arytenoid procedure is planned, the needle is advanced along the posterior edge of the thyroid lamina, staying medial to the carotid artery to anesthetize the inferior constrictor region.

The length of the incision is based on the extent of the surgery that is planned. If an implant medialization laryngoplasty is planned along with an arytenoid procedure, the incision will extend from the contralateral paramidline region through the anterior sternocleidomastoid muscle region. The length of the incision is also determined by the thickness of the soft tissue superficial to the visceral fascia and the extrinsic laryngeal strap musculature.

The incision is extended to the surface of the extrinsic laryngeal musculature. Subplatysmal flaps are raised from the level of the inferior cricoid to the hyoid bone, and Gelpi retractors are placed to maintain the flaps.

A needle-tip electrocautery knife is used on cutting mode to separate the strap musculature in the midline until the thyroid and cricoid cartilages are encountered. A narrow double-prong skin hook is placed in the thyroid notch to rotate the thyroid laminae toward the innervated side and thereby better expose the lamina of the paralyzed vocal fold.

If an arytenoid procedure is to be done, skip to * on page 113.

If a medialization is planned without an arytenoid procedure, the strap musculature except for the thyrohyoid is retracted laterally. The thyrohyoid muscle is
Chapter 17  Laryngeal Framework Surgery

Figure 17–1 Neck incision. (From Zeitels S. M. Adduction arytenopexy with medialization laryngoplasty and crico-thyroid subluxation: a new approach to paralytic dysphonia. Oper Tech Otolaryngol Head Neck Surg 1999;10:9–16. Reprinted with permission.)

Seperated from the inferior thyroid lamina by means of cutting electocautery, which allows for wide exposure of the thyroid ala lateral to the denervated glottal musculature.

- The needle-tip electocautery is then reduced in power and used to outline an inferiorly based U-shaped perichondrial flap on the thyroid ala lateral to the denervated vocal muscles (Fig. 17–2).

- A 2 mm Stryker saw blade is used to create a window through the cartilage that is \(~4 \times 9\) mm. The lower aspect of the window should allow for a stable 2 to 3 mm cartilaginous strut. In men, the thyroid cartilage laminae form a more acute angle than in women. Therefore, in men, the anterior vertical limb of the cartilage window should be \(~3.5\) mm from the anterior aspect of the lamina to avoid overclosure anteriorly. In women, it can be slightly closer.

- With the perimeter of the cartilage window fully mobilized, a small single-prong hook is used to withdraw the window from its in situ position. Some care is taken to preserve the inner perichondrium while the cartilage is being removed.

- Using a duckbill dissector, the soft tissue is dissected from the perimeter of the window. Once this is accomplished, a thin sheet of Gore-Tex® (i.e., cardiac patch) is introduced into the window (Fig. 17–3).

- The duckbill dissector is used to layer the Gore-Tex into position in a gradual fashion while testing the voice. A major advantage of Gore-Tex over other implant models
Figure 17–2 Inferiorly based U-shaped perichondrial flap on the thyroid ala and thyroid cartilage window. (From Zeitels S. M. Adduction arytenopexy with medialization laryngoplasty and crico-thyroid subluxation: a new approach to paralytic dysphonia. Oper Tech Otolaryn Head Neck Surg 1999;10:9–16. Reprinted with permission.)

Figure 17–3 Insertion of Gore-Tex® sheet within thyroid cartilage window. (From Zeitels S. M. Adduction arytenopexy with medialization laryngoplasty and crico-thyroid subluxation: a new approach to paralytic dysphonia. Oper Tech Otolaryn Head Neck Surg 1999;10:9–16. Reprinted with permission.)
is that three-dimensional adjustments in the anatomy are done with simultaneous assessment of vocal function. Once the voice is considered optimal, a visual examination is performed with the fiberoptic laryngoscope.

- If the reconstruction is considered acceptable both acoustically and visually, the perichondrial flap is reapproximated using 4–0 Vicryl sutures.
- If the ipsilateral arytenoid is widely abducted and/or inferiorly displaced and there is adequate abduction of the contralateral arytenoid, an adduction arytenopexy is performed.
- Once the strap muscles are separated in the midline with the needle-tip electrocautery, the strap muscles are then also severed in a transverse fashion.
- Blunt dissection is performed along the lateral thyroid lamina and medial to the carotid sheath. In doing so, a thin double-prong skin hook should be positioned around the posterior edge of the thyroid lamina so that it can be rotated approximately 60 degrees.
- The needle-tip electrocautery is then used to separate the inferior constrictor over the entire posterior border of the thyroid lamina so that the greater and lesser cornua are defined.
- Mayo scissors are used to separate the cricothyroid joint while preserving the inferior cornu. The scissors are then used to separate the cricothyroid joint while preserving the inferior cornu (Fig. 17–4), and the pyriform sinus mucosa is bluntly

Figure 17–4 Separation of the cricothyroid joint with preservation of the inferior cornu. (From Zeitels S. M. Adduction arytenopexy with medialization laryngoplasty and crico-thyroid subluxation: a new approach to paralytic dysphonia. Oper Tech Otolaryn Head Neck Surg 1999;10:9–16. Reprinted with permission.)
dissected from the inner aspect of the lateral thyroid lamina (Fig. 17–5). As necessary, the greater cornu is also mobilized from its superior ligamentous attachments.

Once the cricothyroid joint is separated, this allows for even greater rotation of the thyroid lamina. It also allows for identification of the lateral aspect of the posterior cricoarytenoid muscle. Dissection is done bluntly in a superior fashion along the edge of the posterior cricoarytenoid (PCA) muscle until the muscular process of the arytenoid is encountered. The attachment of the PCA muscle is separated from the muscular process, and the PCA muscle is deflected off the posterior plate of the cricoid (Fig. 17–6).

Figure 17–5 Dissection of pyriform sinus mucosa from the inner aspect of the lateral thyroid lamina. (From Zeitels S. M. Adduction arytenopexy with medialization laryngoplasty and cricothyroid subluxation: a new approach to paralytic dysphonia. Oper Tech Otolaryng Head Neck Surg 1999;10:9–16. Reprinted with permission.)
Figure 17–6 Attachment of the posterior cricoarytenoid (PCA) muscle is separated from the muscular process, and the PCA muscle is deflected off the posterior plate of the cricoid. LCA, lateral cricoarytenoid. (From Zeitels S. M. Adduction arytenopexy with medialization laryngoplasty and crico-thyroid subluxation: a new approach to paralytic dysphonia. Oper Tech Otolaryng Head Neck Surg 1999;10:9–16. Reprinted with permission.)

- In a very careful fashion, posterior and lateral aspects of the cricoarytenoid joint capsule are opened to expose the glistening cricoid facet of the cricoarytenoid joint. Once this is done, the lateral cricoarytenoid muscle fibers are then separated from the muscular process as well. This can be facilitated by the bipolar cautery.
- Next, the arytenoid cartilage is repositioned on the medial aspect of the cricoid facet with a single suture, as seen in Fig. 17–7A–C. That suture is temporarily affixed, and a flexible laryngoscopic examination is performed with the cartilage framework in its normal position. If acceptable, the suture is permanently fixed.
- At this point, a cricothyroid subluxation must be done for two reasons. First, the denervated paraglottic musculature will have an enhanced resonant frequency if a
unilateral stretching procedure is performed. Second, the separated cricothyroid joint leads the thyroid lamina to become retrodisplaced, which results in a more flaccid ipsilateral vocal fold.

- The cricothyroid subluxation procedure simulates the vector contraction of the cricothyroid muscle. It is done by affixing a 2–0 Prolene suture around the inferior cornu and subsequently passing the suture in a submucosal fashion under the anterior aspect of the cricoid cartilage (Fig. 17–8A,B).

- Once that suture is passed, gradual tightening is done with a slip knot, which can be released so that the voice can be tested at various pitch frequencies and loudness. Ideally, the patient should be able to phonate in a falsetto register yet also achieve a lower-pitch conversational-level pitch frequency. Once this is achieved, the suture is permanently affixed.

- A final flexible laryngoscopic examination is done to confirm the anatomical repositioning.

Figure 17–7 (A–C) The arytenoid cartilage is repositioned on the medial aspect of the cricoid facet. (From Zeitels S. M. Adduction arytenopexy with medialization laryngoplasty and cricothyroid subluxation: a new approach to paralytic dysphonia. Oper Tech Otolaryn Head Neck Surg 1999;10:9–16. Reprinted with permission.)
Figure 17–8 (A) Affixing a 2–0 Prolene suture around the inferior cornu in the cricothyroid subluxation procedure. (B) Passing the Prolene suture in a submucosal fashion under the anterior aspect of the cricoid cartilage. (From Zeitels S M. Adduction arytenopexy with medialization laryngoplasty and crico-thyroid subluxation: a new approach to paralytic dysphonia. Oper Tech Otolaryng Head Neck Surg 1999;10:9–16. Reprinted with permission.)
At this point, the strap muscles are reattached with 3–0 Vicryl sutures. A $\frac{1}{4}$ inch Penrose drain is placed, and the platysma layer is closed over the drain. Finally, the skin is closed with 4–0 nylon in an interrupted or running fashion. An elastic pressure dressing is then applied. Initially, the drain was removed on the postoperative day; however, over time the decision was made to leave the drain in for several days to avoid difficulties with a seroma or hematoma. This is especially so if extensive dissection is done, which is associated with an arytenopexy.

**Postoperative Care**

- The most frequent substantial complication associated with this procedure is that of hemorrhage and subsequent airway impairment. It is very common for there to be substantial periarytenoid and aryepiglottic fold edema several days postoperatively, even if there has been no hemorrhage. Therefore, most patients will complete the previously prescribed Medrol dose pack upon their discharge.
- The Penrose drain can be removed anytime after postoperative day 1, and skin suture removal is done at 1 week.
- Patients should be prepared that there will be variations in their voice over the first several weeks as a result of edema and final healing as well as reconditioning vocal behavior. Readjusting vocal kinetics is often more difficult in those who are older due to diminishing central nervous system plasticity and in those who have been paralyzed for a longer period of time. Patient should be prepared for six to eight sessions of weekly vocal rehabilitation therapy despite the fact that most will not require it beyond four to six sessions.
The essential point to be made in a discussion of thyroid and parathyroid surgery is that meticulous surgical technique is paramount. This is crucial for appreciation of neck base anatomy, including recurrent laryngeal nerve and parathyroid recognition and preservation.

**Thyroid Surgery**

**Surgical Technique**

*Patient Positioning/Incision*

- An inflatable thyroid bag or thyroid roll is placed under the shoulders, and important attention is given to adequate head support. Once the patient is positioned, the surgical bed is placed in a semi-sitting position to decrease venous pressure. The eyes are lubricated and taped.
- We typically employ 10 mg of Decadron® (dexamethasone) to help reduce the risk of neuropraxic nerve injury. With recurrent laryngeal nerve monitoring, muscle relaxation is avoided.
- A 4 to 5 cm collar-type thyroid incision is made one thumb breadth below the cricoid. An incision that is too low, especially if the neck is thin, can cause excessive scarring in the suprasternal notch region.

*Subplatysmal Skin Flap*

- A subplatysmal skin flap is raised to approximately the level of the superior thyroid cartilage. The anterior jugular veins are let down. It is infrequent that an inferior flap needs to be raised.
Identification of the Airway

- The strap muscles are dissected in the midline with identification of the medial edge of the sternohyoid muscles and sternothyroid muscles.
- The cricoid cartilage, the cricothyroid membrane, the thyroid cartilage, and the trachea above and below the isthmus are dissected. This allows identification of any prelaryngeal or pretracheal adenopathy and also allows identification of the pyramidal lobe should it be present.

Strap Muscles

- The strap muscles are reflected off the ventral surface of the thyroid gland. This is facilitated by medial retraction of the thyroid gland opposing the lateral retraction of the strap muscles. Strap muscles can be divided in cases of goiter.
- The middle thyroid vein is visualized, clamped, and tied with 2–0 silk.

Inferior Pole

- With slight upward and medial thyroid retraction and lateral strap muscle retraction, the inferior pole of the thyroid is dissected on a capsular plane. Usually several small inferior ventral thyroid veins can be clamped and tied.
- The inferior parathyroid typically resides in fat adjacent to the inferior pole, often in the thyrothymic horn itself. This fat and the inferior thyroid can be brushed away from the thyroid as these inferior thyroid pole veins are taken. A parathyroid

Figure 18–1 The inferior parathyroid can be found adjacent to the inferior pole in thyrothymic horn fat. (From Randolph G. Surgery of the Thyroid and Parathyroid Glands. Philadelphia: Saunders; 2003. Reprinted with permission.)
gland that has good color, has not been dissected from the surrounding fat, and has a laterally oriented pedicle at the end of the case can be relied on for postoperative function (Fig. 18–1).

Recurrent Laryngeal Nerve

- This is best identified at the midpolar level. Recurrent laryngeal nerve stimulation can be performed through the overlying fascia to identify the nerve even prior to

Figure 18–2 The recurrent laryngeal nerve is shown in the tracheoesophageal groove, piercing the ligament of Berry and extending under the inferiormost fibers of the inferior constrictor. The left thyroid cartilage is removed in this illustration to show intralaryngeal nerve anatomy. (From Randolph G. Surgery of the Thyroid and Parathyroid Glands. Philadelphia: Saunders; 2003. Reprinted with permission.)
visualization. Gentle dissection with a snap parallel to the anticipated direction of
the nerve is best.
• The nerve in this area can be identified as it crosses above or below the inferior thy-
roid artery. The inferior thyroid artery in the lateral thyroid region can be identified
after the middle thyroid vein has been taken through a gentle pulsation.
• The recurrent laryngeal nerve above the inferior thyroid artery may branch. All
branches must be preserved. The recurrent laryngeal nerve does not need to be dis-
sected along its entire path in this area. The dissection can be through several windows
through which the path of the nerve is fully seen. This helps to preserve medially run-
ning branches of the inferior thyroid artery. The nerve at this point is dissected up to
where it dives underneath the thyroid lobe, toward the ligament of Berry (Fig. 18–2).

Superior Parathyroid

• Before the superior pole is taken, the superior parathyroid is identified on the pos-
terolateral aspect of the superior pole under fascia in this region. It generally rests
in fat in this location. It is best to create a plane between the superior parathyroid
posteriorly (i.e., dorsal) and the posterolateral aspect of the superior pole, which,
when retracted, is ventral. If possible, we prefer to dissect the superior parathyroid
away from the superior pole prior to taking superior pole vessels because we feel
this may help preserve superior pole posterior branches, which may in part vascu-
larize the superior parathyroid (Fig. 18–3).

Figure 18–3 The superior parathyroid is identified in fat adjacent to the lateral aspect of the
superior pole directly lateral and dorsal to the recurrent laryngeal nerve entry site. (From
Reprinted with permission.)
Superior Pole

- The thumb and forefinger retract the superior pole laterally and inferiorly to open up the space between the medial aspect of the superior pole and the lateral aspect of the larynx. The ventralmost superior pole vessels then can be clamped and tied on a strictly capsular plane.
- Prior to taking the superior pole vessels, the external branch of the superior laryngeal nerve can be visually identified and in all circumstances electrically identified to assure the surgeon that it is medial on the inferior constrictor rather than caught up in branches of the superior pole vessels and potentially at risk during superior pole vessel management. The vessels should be taken on a strictly capsular plane under direct visualization. Posteriormost branches of the superior pole artery can be brushed posteriorly and left intact so as to provide for vascularization of the superior parathyroid that has also been dissected posteriorly and away from the thyroid superior pole (Fig. 18–4).

Medial Rotation of the Thyroid and the Presentation of the Ligament of Berry

- At this point the inferior pole has been dissected and can be reflected cranially. The superior pole also has been dissected and can be reflected caudally and up onto the trachea. With a gauze, the surgeon retracting the thyroid can medially rotate the thyroid and in this way present the deepest aspect of the midpolar region and ligament of Berry.
- The dissection of the recurrent laryngeal nerve resumes, and the recurrent laryngeal nerve is followed up and through the ligament of Berry with all branches being preserved. Just lateral and deep to the recurrent laryngeal nerve's entry point into the larynx under the lowest fibers of the inferior constrictor can often be found the superior parathyroid, if it has not already been identified.
- There is often a specific branch of the inferior thyroid artery in this region feeding the ligament of Berry region. This artery, as with all branches of the inferior artery, should be taken as medially as possible with full view of the recurrent laryngeal nerve.
- A small amount of bleeding as dissection proceeds through the ligament of Berry is typical and often will respond to gentle pressure with gauze for several moments. It is best not to indiscriminately clamp or cauterize bleeders in this area. A bipolar cautery is the best instrument for careful cautery in this area (Fig. 18–5).
- Once the ligament of Berry is dissected, the thyroid can be rotated off the anterolateral trachea and the isthmus stump clamped and tied with 2–0 silk.
- If a total thyroidectomy is planned, then the opposite lobe is treated similarly. If a hemithyroidectomy is planned, then the surgery is complete. If a hemithyroidectomy is planned, it is best to palpate the opposite lobe through the strap muscles rather than reflect the strap muscles off the remaining lobe, as this can engender substantial scarring that would complicate any additional necessary surgery at a later time.
- The thyroid specimen that has been resected prior to being sent off the field is examined. Any potential capsular parathyroid tissue can be identified. A small portion of the parathyroid gland can be sent to confirm its identity with frozen section,
and the remaining portion of the parathyroid gland can be diced into small 1 mm pieces and then autotransplanted into two or three ipsilateral sternocleidomastoid muscular pockets, each marked with a clip. Similarly, the thyroid bed is examined, and any parathyroid glands that have clearly insufficient vascular pedicles or are intensely black should be sampled for frozen section and then minced and autotransplanted.

**Closure**

* At this point, this author irrigates with antibiotic-containing saline and have the anesthesiologist give several high-pressure ventilations to confirm good hemostasis.
Once this is done, we typically place Surgicel overlying the ligament of Berry region, then close the strap muscles in the midline and platysmal layer with 3–0 Vicryl. The incision is closed with interrupted 5–0 nylon removed on postoperative day 1 and then reclosed using Steri-Strip. Avoidance of skin edge stretch during the procedure and careful closure of the subcutaneous tissue, allowing good skin edge approximation, are probably the most important steps in having an ideal scar.

Near Total Thyroidectomy

Surgery for thyroid nodularity and goiter may include hemithyroidectomy, total thyroidectomy, or near total thyroidectomy. One must understand that total...
thyroidectomy, even in experienced hands, can lead to thyroid bed uptake that requires ablation in 20 to 40% of cases. Given this, intentionally leaving a small segment of contralateral anodular, normal-appearing thyroid tissue is a very reasonable maneuver if the surgeon feels that parathyroid preservation can be more reasonably achieved.

- Near total thyroidectomy involves leaving a small remnant of thyroid tissue to decrease the degree of parathyroid dissection that is necessary on this contralateral side. This typically involves leaving an elliptical posteriormost portion of the thyroid lobe amounting to several grams. It is important to not dissect the lateral thyroid region in this area to prevent disturbance of parathyroid gland blood supply.

Recurrent Laryngeal Nerve Monitoring

- Recurrent laryngeal nerve monitoring can be useful in identification of the nerve and can be tremendously helpful in dissecting the nerve, especially in the ligament of Berry region.
- The most important application of recurrent laryngeal nerve monitoring is at the completion of lobectomy, when the nerve can be stimulated to be sure that it has not been injured during surgery. Electromyogram monitoring and laryngeal palpation in no way replace the need for visual identification of the nerve.

Managing Nerve Injury

- Should nerve transection be identified during surgery, primary tension-free neurorrhaphy with two to four fine 9–0 sutures should be performed. If there is segmental loss of the nerve, the distal recurrent laryngeal nerve stump can be anastomosed to the ansa cervicalis.
- Nerves that are judged to be injured through compression or stretch injury should be treated with perioperative steroids, with good functional recovery expected.

◆ Parathyroid Surgery

Surgical Indications

- Surgery represents the mainstay of treatment for hyperparathyroidism.
- All patients under 50 years of age are considered for surgery because of the potential for the development of symptoms if followed nonsurgically.
- All patients over age 50 are considered surgical candidates if they have developed a complication of HPT or a suggestion of impending complication based on focused lab assessment
  - Such as the development of renal nephrolithiasis
  - Calcium elevations greater than 11.5 mg/dL
  - One or more episodes of life-threatening hypercalcemia
  - Evidence of substantial bone loss (bone density studies showing greater than 3 standard deviations when matched by race, sex, and age)
Evidence of renal dysfunction as indicated by creatinine clearance decreased by 30%.

An elevated urinary calcium greater than 400 mg/dL.

Localization Studies

- These are helpful in patients being offered minimal access parathyroid surgery for single-gland disease.
- We prefer sestamibi scan with single photon emission computed tomography (SPECT) and sonography to localize a hyperfunctional enlarged parathyroid.

Minimal Access Approach

- A limited uniglandular approach is performed when both sestamibi scan and sonogram indicate a single focus of abnormality.
- The ipsilateral thyroid gland is typically not visualized using this approach. The approach is reliant on preoperative localization studies to determine where minimal access surgery should begin and on intraoperative parathyroid hormone (PTH) assay to determine when dissection can be halted. Any surgeon employing minimal access approach must be prepared to convert to a standard unilateral or bilateral approach, depending on intraoperative information.

Surgical Technique

- Initial patient positioning is as for thyroid surgery.
- If preoperative localization tests suggest superior parathyroid gland disease, then the superior pole is dissected posteriorly, and the posterolateral margin of the superior pole is dissected and palpated. The superior parathyroid gland can descend in the neck, so the prevertebral fascia should be palpated in retrolaryngeal and retroesophageal locations.
- If an inferior parathyroid gland is suspected based on preoperative localization tests, then the inferior pole of the thyroid region is dissected initially.
- Keep in mind that localization tests simply determine which quadrant of the neck is positive. A superior parathyroid gland adenoma that has migrated inferiorly may give inferior quadrant positivity. So too (though less common), an undescended inferior parathyroid may give superior quadrant positivity. One should note that when bilateral dissection is necessary, there is parathyroid gland symmetry from side to side in terms of location and shape.
- During parathyroid surgery, normal parathyrds are to be identified and in some circumstances biopsied but never removed. Enlarged glands should be taken out completely and not biopsied to prevent seeding of the wound with adenomatous tissue, leading to recurrent hyperparathyroidism.
- Depending on preoperative localization tests and intraoperative PTH assay findings, the surgery may be concluded with dissection and removal of an enlarged single gland. Intraoperative PTH assay at 10 minutes after excision should be less than 50% of the initial baseline value and should be within the normal range of 10 to 65. Frozen section can also be used to determine that the lesion dissected is in fact hypercellular parathyroid gland with decreased stromal fat.
Table 18–1 Parathyroid Location: Normal, Embryological, and Acquired Variations

<table>
<thead>
<tr>
<th>Normal</th>
<th>Normal Embryological</th>
<th>Acquired Migrated</th>
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<tbody>
<tr>
<td>Superior parathyroid (PIV)</td>
<td>80% within 1 cm cricothyroidal cartilage junction (1 cm cranial to ITA/RLN crossing)</td>
<td>15% on posterolateral surface of upper half of thyroid lobe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3% retrolarynx, retroesophageal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1% above superior pole</td>
</tr>
<tr>
<td>Inferior parathyroid (PIII)</td>
<td>50% within 1 cm inferior pole (inferior, lateral, posterior)</td>
<td>25% thyrothymic horn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3% anterior mediastinum, lower thymus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12% &gt; 1 cm lateral to inferior pole</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8% medial on trachea</td>
</tr>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

Percentages are for normal, nonadenomatous glands.
ITA, inferior thyroid artery; RLN, recurrent laryngeal nerve; STA, superior thyroid artery.

- If the parathyroid glands cannot be identified in their normal locations, dissection should be performed in less likely regions where the parathyroid glands may occur (Table 18–1).
- If the lower gland is missing, meticulous dissection at the inferior thyroid bed adjacent to the inferior pole, including superior mediastinum and thymus, is
performed. This is assisted by identifying and following the distal branches of the inferior thyroid artery. The thymus should be fully explored and can be resected. Further attempts at localization of the inferior parathyroid gland can extend to the carotid sheath from the level of the hyoid to the thoracic inlet and lateral to the carotid sheath in the scalene fat pad.

If the superior parathyroid gland is missing, meticulous dissection is performed around the superior pole, checking parapharyngeal, retropharyngeal, and esophageal locations, extending the search downward into the posterior mediastinum. The prevertebral fascia is incised from the inferior thyroid artery to the superior pole. The search is conducted emphasizing the regions deep to the recurrent laryngeal nerve (Fig. 18–6). If such dissection is unrevealing, then one may consider the entity of intrathyroidal parathyroid adenoma. A thyroidotomy will be sufficient to identify such intrathyroidal parathyroid glands. It is best not to empirically offer a unilateral or bilateral thyroidectomy, as this can significantly increase scarring and make more complex any revision exploration.
19
Cancer Surgery of the Neck
Richard L. Fabian

The predominant pathology that the surgeon encounters in the neck is abnormal lymph nodes. The scope of this chapter is to focus on malignant cervical lymphadenopathy.

◆ Neck Dissection

Surgical Anatomy

◆ Cervical lymph nodes are grouped into several levels

  ◦ Level 1a, Submental Triangle   Nodes between the anterior belly of the digastric muscles
  ◦ Level 1b, Submandibular Triangle   Nodes within the triangle bordered by the anterior and posterior digastric muscles
  ◦ Level 2, Upper Jugular   Nodes associated with the internal jugular vein (IJV) from the skull base to the carotid bifurcation; 2a nodes are medial anterior to the ninth cranial nerve (CN IX), and 2b nodes are posterior lateral to CN XI to the skull base.
  ◦ Level 3, Middle Jugular   Nodes between the carotid bifurcation and omohyoid muscle
  ◦ Level 4, Lower Jugular   Nodes between the omohyoid muscle and clavicle
  ◦ Level 5, Posterior Triangle   Nodes between the clavicle, trapezius, and sternocleidomastoid (SCM) muscle
  ◦ Level 6, Visceral Compartment   Nodes along the anterior midline between the carotid arteries, manubrium, and hyoid
Chapter 19  Cancer Surgery of the Neck

Level 7, Superior Mediastinum  Nodes between the carotid arteries from the manubrium to the innominate vein

Classification

Neck dissection is a surgical procedure whereby a surgeon removes lymph nodes from the cervical lymphatic region. Neck dissection is classified as follows:

- **Radical neck dissection**  Resection of nodes in levels 1 through 5, including the SCM, internal jugular vein, submandibular gland, and spinal accessory nerve. Nodes that are not addressed in a radical neck dissection are the facial, intra-parotid, retropharyngeal, occipital, postauricular, supraclavicular, and anterior superficial and deep lymph nodes.

- **Modified neck dissection**  Preservation of one or more of the nonlymphatic structures removed in a radical neck dissection.

- **Selective neck dissection**  Preservation of one or more of the lymph node groups ordinarily removed in a radical neck dissection. This group is subdivided into a supraomohyoid (levels 1–3), lateral (levels 2–4), posterolateral (levels 2–5, including postauricular and suboccipital nodes), and anterior neck dissection (level 6 nodes).

- **Extended neck dissection**  The inclusion of a region, lymphatic structure, or nodal group in addition to those removed in a radical neck dissection. These structures include lymph nodes in the retropharynx, mediastinum, buccinator and paratracheal space, deep muscles of the neck, sections of the carotid system, nerves such as the hypoglossal, vagus, phrenic, lingual, and facial, and segments of the brachial plexus, as well as portions of the clavicle and hyoid bone.

- **Functional neck dissection**  Serves to remove nodes from levels 1 through 5 without removing any nonlymphatic structure. This operation is technically the most demanding because a complete cervical lymphadenectomy is the oncological intent. Nodes in the high spinal accessory group and level 2a (coffin corner) can easily be missed with subsequent disastrous consequences.

Surgical Technique

Positioning and Surgical Draping

- The shoulder is elevated with a shoulder roll, allowing for full extension of the neck. The occiput rests on a foam-contoured pillow.

- The table is elevated 30 degrees to help reduce operative bleeding.

- A wide-field prep using a head drape and towels allows for the perimeter exposure of the ear lobe, border of the trapezius, clavicle, anterior neck to the contralateral submaxillary triangle, and lower border of the mandible.

Incision and Skin Flaps

- Variables to consider when deciding on the skin incision include the following.

  - Is the neck dissection unilateral or bilateral?
  - Is the dissection part of the resection of the primary tumor?
Where is the primary tumor located?

Is there a high probability of a future neck dissection on the contralateral side?

The two incisions that allow the surgeon to manage most variables are the modified Conley incision and apron flap.

All preliminary incisions done on a neck (node biopsy) should anticipate a potential neck dissection. This allows the surgeon to place a previous biopsy site incision in line with the incision for the neck dissection.

The advantages of the modified Conley incision include:

- Excellent exposure and cosmesis
- Trifurcation incision junction is posterior to the great vessels.
- Prevents contraction of the vertical limb by designing a serpiginous incision
- Allows for simultaneous surgery on all primary sites above the thyroid notch as well as bilateral neck dissection

The apron flap is convenient for bilateral neck dissections, especially when combined with a total laryngectomy or thyroidectomy.

For combined laryngeal surgery, a high apron flap with a midline neck incision from the hyoid to cricoid allows for removal of the primary tumor and neck dissection. Neck exposure at the deltoid–trapezius junction is limited.

A low unilateral apron flap limits dissection in region 1a.

All incisions and adjacent skin are infiltrated in the subdermal plane with 1:100,000 epinephrine without lidocaine to maximize hemostasis and prevent interference with intraoperative neural stimulation.

The modified Conley incision consists of horizontal and vertical components. The horizontal component is made three fingerbreadths below the lower border of the mandible from chin to mastoid. The vertical component intersects the horizontal incision one quarter of the distance from the mastoid tip. It reaches the posterior clavicle in a lazy S fashion to prevent postoperative contracture.

Flap elevation is subplatysmal to improve flap blood supply. Elevation extends to the clavicle, hyoid group of muscles, lower border of the mandible, and trapezius. Care is taken not to communicate with the tracheostomy dissection bed.

The remaining description will outline important technical points in doing a radical neck dissection. Exposure for a modified or functional neck dissection can approach that of a radical dissection by dividing the lower one third of the SCM.

**Radical Neck Dissection: Anatomical Regions**

The neck is divided into anatomical regions. Each region encloses important anatomical structures that should be identified. This approach allows the surgeon to select any quadrant as the starting point in a neck dissection because the size, location, and nature of the pathologic process will dictate different approaches.

- Superior anterior region
  1. Contents of the submaxillary and submental triangle
  2. Lingual artery, lingual nerve, hypoglossal nerve, ramus mandibularis, anterior facial vein
Chapter 19  Cancer Surgery of the Neck

- Superior posterior region
  1. Transverse process of the atlas (C1)
  2. SCM
  3. Ramus mandibularis
  4. Retromolar vein
  5. Accessory nerve
  6. Internal jugular vein
  7. Vagus nerve
  8. Hypoglossal nerve
  9. External jugular system

- Inferior medial region
  1. SCM
  2. Internal jugular vein
  3. Carotid artery
  4. Thyroid vein
  5. Vagus nerve
  6. Thoracic duct
  7. Phrenic nerve
  8. Terminal end of the external jugular system

- Lateral inferior region
  1. Spinal accessory nerve
  2. Transverse cervical artery and vein
  3. Brachial plexus

Nerve Identification and Preservation

- Ramus mandibularis  The ramus emerges from the parotid tail, courses over the submandibular triangle, and enters the depressor muscles of the face. It runs below the plastysma and deep to the superficial layer of the deep cervical fascia. Preservation is by direct identification of the nerve using a stimulator, division of the anterior facial vein, and dissecting deep to the vein that is retracting the nerve laterally and raising a plane deep to the superficial deep fascia layer from the inferior border of the submaxillary gland.

- Lingual nerve  The lingual nerve is easily identified in the submaxillary triangle. After preservation of the ramus mandibularis, the submaxillary gland is separated anteriorly and superiorly from the anterior fibers of the digastric muscle. Deep to the digastric muscle, fibers of the mylohyoid muscle run from anterior-inferior to posterior-superior. Finger dissection posterior to the mylohyoid fibers with retraction of the muscle superior medially with a Richardson retractor will yield immediate identification of the lingual nerve. The nerve gives parasympathetic fibers to the submaxillary gland. Division of these fibers during gland removal should be done carefully. The hemostat should be applied to the branch
well above the main trunk, with the curve of the hemostat corresponding to the
curve of the lingual nerve.
◆ Hypoglossal nerve  The hypoglossal nerve is best identified in the inferior medial
quadrant of the submaxillary triangle. Blunt dissection to the floor of the triangle
and retraction of the anterior digastric belly anteroinferiorly will reveal prominent
veins accompanying the hypoglossal nerve, which angles across the floor of the
triangle in an anterior to posterior direction. Nerve stimulation will confirm its
existence. The hypoglossal nerve can be followed into the posterior neck from the
triangle as it passes under the posterior belly of the digastric muscle. Division of
the digastric muscle will sometimes simplify the dissection.
◆ Spinal accessory nerve  Release and retraction of the superior medial border of the
SCM, mobilization of the parotid tail, and identification and retraction of the pos-
terior belly of the digastric muscle will reveal the spinal accessory nerve coursing
over the posterior aspect of the internal jugular vein. With the SCM elevated and
retracted, the spinal accessory nerve penetrates the SCM in 75% of patients and
emerges at Erb's point. From this point, sensory branches of C2–C3 and the spinal
accessory nerve radiate in a 180-degree arc. The use of a stimulator facilitates the
identification of the accessory nerve at Erb's point. Injury to the nerve usually
occurs medial to Erb's point, where the sensory branches and the branch to the
SCM may be confused. The nerve stimulator is an invaluable tool here.
◆ Vagus nerve  The vagus is identified any place along the carotid sheath. The time-
honored method is to divide the medial limb of the omohyoid muscle, dissect and
retract the internal jugular vein laterally, and locate the nerve posterior and lateral
to the carotid artery. Care must be taken to identify an occasional anteriorly placed
nerve. The sympathetic nerve is located medial and posterior to the carotid artery.
Injury to this will result in Horner's syndrome.
◆ Phrenic nerve and brachial plexus  Lymphatic-bearing tissue lateral to the internal
jugular vein in the inferior region will reveal the deep layer of the deep cervical
fascia carpet. Crossing the anterior scalene muscle will be the phrenic nerve that,
when identified, will stimulate quite briskly. Because most injuries to this occur
higher in the neck, the nerve should be visually dissected superiorly until freed
from the overlying specimen.

The brachial plexus is located deep to the deep layer of deep cervical fascia, behind
the inferior belly of the omohyoid muscle. It emerges between the anterior and
medial scalene muscle. Higher in this area the brachial plexus can be confused with
the sensory cervical plexus, leading to an inadvertent injury. When dividing the cer-
vical plexus branches, nerve stimulation will prevent inadvertent injury to the
brachial plexus and phrenic nerve.

◆ Superior laryngeal nerve  The superior laryngeal nerve lies posterior to the inter-
nal and external carotid arteries above the bifurcation. Before entering the larynx,
it divides into an external and internal branch. Isolation of the carotid and jugular
vein system medial to the bifurcation if taken posteriorly can result in injury to
this nerve. In patients with borderline swallowing problems, loss of sensation of
the piriform sinus or weakness of the cricothyroid muscle can result in permanent
swallowing injury with aspiration.
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Vessel Identification

- The facial vein and artery are located posterior to the submaxillary gland. Both pass close and posterior to the superior aspect of the gland, giving small branches to the gland. The mandibular notch is also a constant location for both vessels. This area is also crossed by the ramus mandibularis nerve.
- The carotid arterial system and IJV can be found in two constant locations. Inferiorly, the omohyoid muscle crosses both vessels as it departs from the lateral border of the larynx. Division of the omohyoid in this location puts the surgeon over the IJV and carotid sheath that is located medial to the vein.
- Superiorly, palpation of the transverse process of the first cervical vertebra identifies the following structures that are positioned over and medial to the process: From lateral to medial are CN IX, the IJV, the vagus nerve, the internal and external carotid arteries, and CN XII.
- The external jugular vein is positioned next to the greater auricular nerve as it crosses the upper one third of the SCM.

IJV Ligation

- Division of the omohyoid muscle in the inferior medial quadrant allows for identification of the lower portion of the IJV. The carotid sheath lies medial to it. The lowest portion of the IJV lies immediately below the triangular notch between the clavicular and sternal attachment of the SCM. The vein is immediately posterior to the omoclavicular fascia. The middle thyroid vein and branches from the external and anterior jugular system need to be divided and doubly ligated before safe isolation of the vein can commence. The vein is then separated from the carotid sheath. Special attention should be paid to the location of the vagus, which is dissected free of the vein. All tissue lateral to the vein needs to be ligated between snaps to avoid this.
- Once isolated, the lower vein is clamped with four hemostats placed from medial to lateral to avoid a tip clamping of the vagus nerve. After division, the upper and lower ends are freed, tied with 2–0 silk, and suture ligated with the same material.
- The upper segment of the vein is isolated from the carotid artery, vagus, and CN XI, and it is clamped, divided, and ligated in exactly the same fashion as the lower segment. Base of skull disease may result in difficulty controlling the upper divided segment of the IJV. Packing the vein with Surgicel® and applying surgical clips will usually be sufficient to control this event.

Identification of the Thoracic and Lymphatic Duct

- The left thoracic duct emerges from the superior mediastinum, next to the subclavian artery, along the medial border of the anterior scalene muscle, where it is joined by the left jugular, left subclavian, and left mediastinal trunk before it drains into the IJV. The right jugular, subclavian, and mediastinal trunks usually drain independently into the right IJV.
All lymphatic-bearing tissue medial to the phrenic and lateral to the lower end of the IJV must be isolated carefully, clamped, and tied to prevent a lymphatic leak.

Using anesthesia to do a Valsalva maneuver will help identify an intraoperative chyle leak. This must be dealt with definitively, sometimes employing the operative microscope to ligate or oversew the leak. The application of a Surgicel cigarette soaked with doxycycline will cause an increased inflammatory reaction and facilitate scarring of the area.

**Node Removal**

Lymphatic-bearing tissue is removed from the neck by dissecting levels 1 through 4 away from the underlying muscles, nerves, and vessels. In region 5, nodal-bearing tissue is swept off the deep layer of the deep cervical fascia dividing the penetrating branches of the cervical plexus.

Nodes within level 2b are more difficult to remove in a functional or modified neck dissection. As previously mentioned, division of the lower portion of the SCM will facilitate this. Care must be taken to avoid injury to the spinal accessory and ramus mandibularis nerves because this area includes a portion of the parotid tail and nodes lateral to the IJV and posterior to the upper SCM. Traction injury to the spinal accessory nerve is common in this area.

Nodes in the submental triangle (level 1a) are often forgotten, with potentially serious consequences. This author feels that 1a nodes from both sides should be cleared because cross-lymphatic flow is common.

Paratracheal nodes require identification of the recurrent laryngeal nerve. This can be confirmed by placing a finger behind the cricoid cartilage, stimulating the vagus nerve, and feeling for vocal cord movement. An alternative is to use a recurrent laryngeal nerve monitoring system, which is now commercially available.

The thyroid lobe or lobes are resected when a glottic or subglottic carcinoma of the larynx has penetrated the cricothyroid membrane or strap muscle. This finding is identified by preoperative assessment of the laryngeal tumor clinically, radiographic studies, intraoperative observation, or with advanced disease associated with paraglottic invasion.

Intraoperative suture marking of the nodal regions will help the pathologist accurately report positive node locations.

**Wound Closure**

All neck dissections require closed suction drainage to avoid a postoperative hematoma or seroma and to help identify a chyle leak early.

A no. 19 French Silastic® drain with grenade suction is easy to manage. It is placed anterior and posterior to the carotid artery, in a continuous loop, covering the entire bed of the dissection.

The incision is best closed in three layers with an absorbable suture. The layers are the platysma muscle, subcutaneous layer, and skin. With careful closure of the deeper layers, the skin may be closed with 6–0 chromic suture, staples, Steri-Strips®, or tissue glue.
Common Noncancerous Masses in the Neck

- Midline neck masses
  - Thyroglossal duct cysts
  - Dermoid cysts
  - Lymphangiomas (cystic hygromas)
- Lateral neck masses
  - Lymph nodes
  - Lipomas
  - Branchial cleft anomalies

Timing of Surgery

- When possible, delay surgery on infants (< 6 months) and toddlers because minimal blood loss represents a substantial volume in the small child.
- Avoid resecting infected masses. A 6-week “cooling off” period is usually recommended.

Potential Pitfalls

- Position the patient so maximum surgical field visualization will be attained.
- Use nerve monitoring whenever possible.
Although small incisions are desirable, adequate visualization of the operative field is key. Drain operative fields regardless of admission requirement. Anticipate airway impingement or subsequent swelling in large upper neck lesions.

Thyroglossal Duct Cysts

Indications for Surgical Removal

- Recurrent infections
- Compressive symptoms
- Cosmetic appearance
- Coexistent malignancy

Surgical Technique

- Surgery is performed under general anesthesia. Avoid muscle paralysis to allow for nerve monitoring and stimulation.
- A small shoulder roll is placed to slightly extend the neck.
- Prep from the lower face to the clavicles to allow access to the oral cavity.
- The incision is injected with lidocaine 1% with epinephrine 1:100,000. Avoid injecting into the cyst or mass.
- Make the incision in a line of relaxed skin tension. Excise an ellipse of skin for any dimple or sinus tract.
- Superior and inferior subplatysmal skin flaps are elevated above the hyoid and to the thyroid cartilage. Retract strap muscles laterally. Cysts that have been infected or previously operated on may require sacrifice of adherent strap muscles.
- The hypoglossal nerve will usually course just lateral and superior to the greater horn of the hyoid bone.
- During superomedial dissection, avoid transection of the thyroglossal duct tract.
- The cyst and the central portion of the strap muscles should be followed up to the hyoid bone. A clamp can then be used to grasp the hyoid.
- Always visualize the thyroid cartilage notch to avoid accidental trauma to the laryngeal framework if the thyroid cartilage were mistaken for the hyoid bone. This problem is more likely to occur in younger children where the thyroid cartilage is small, located in a high position, and very close to the hyoid.
- Using Mayo scissors or a bone rongeur, the hyoid bone is cut just medial to the lesser horn. This allows the attachment of the stylohyoid and digastric muscle to remain, stabilizing the remaining hyoid and also avoiding injury to the hypoglossal nerve.
- If a sinus tract exists, it must be followed into the base of the tongue. Palpate the base of the tongue and avoid inadvertent entry into the aerodigestive tract. Apply gentle traction to prevent avulsion of the cyst and stalk as they are traced to the base of the tongue.
- If the cyst is inadvertently breached, the contents can be gently suctioned, followed by the use of a lacrimal probe placed into the cyst and used to trace the stalk.
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◆ The course of the tract may take an inferior route prior to superior ascent and should be followed closely to be sure it is not transected prematurely.
◆ The specimen should contain the cyst, the midportion of the hyoid, a portion of the base of the tongue, and occasionally a portion of the midline strap muscles.
◆ The wound is irrigated and closed in layers with resorbable sutures. Absorbable cutaneous sutures are very useful in children.
◆ Drainage is provided by a suction drain or a small Penrose drain/rubber band and is removed on the first postoperative day.
◆ Thyroglossal duct cysts may contain the only functioning thyroid tissue. If the thyroglossal duct cyst is removed with thyroid tissue, postoperative thyroid-stimulating hormone (TSH) levels should be checked 6 weeks after surgery.

◆ Cervical Dermoid Cyst

Surgical Indications/Considerations
◆ Cosmetic appearance
◆ Concern for pathologic diagnosis on part of patient/family
◆ Recurrent infection
◆ Compressive complaints
◆ These cysts may mimic thyroglossal duct cyst in relation to appearance and position
◆ May also present in neck and yet extend into or near oral cavity

Surgical Technique
◆ Procedure is usually performed under general anesthesia with care to avoid longer lasting muscle relaxants.
◆ Place a roll under the shoulders and the head in the midline.
◆ Inject the proposed line of incision with 1% lidocaine with 1:100,000 parts epinephrine prior to prepping to give the hemostatic properties to take effect.
◆ If the cyst has associated skin changes, that portion of the skin should be included in the incision as an ellipse.
◆ Skin incisions should be attempted to be placed in to skin lines of reduced tension.
◆ Once incision is made, subplatysmal skin flaps are elevated inferiorly and superiorly.
◆ Usually the cyst is identified superficial to the strap muscles; at times however, the strap muscles may require dissection in the midline with retraction laterally.
◆ Once the cyst is visualized, it is grasped and carefully dissected free from surrounding structures using a great deal of care to avoid vital structures.
◆ Usually in the midline the important structures to avoid include the hypoglossal nerve and possible entering the pharynx for high-riding cysts.
◆ Care also should be taken to follow any cystic remnants both superior and inferior to decrease the chance of recurrence.
◆ Once cyst has been removed, irrigate the wound and approximate the strap muscles back into position.
A drain, usually a Penrose or rubber-band, is placed into position and secured to the skin with a single stitch.

The subcutaneous tissue is closed and the skin is approximated with the surgeon's choice of a subcuticular, skin (fast-absorbing), or dermabond adhesive.

Children are usually observed for 23 hours. Adults, however, could be done on an outpatient basis, medical condition permitting.

Apply a non-occlusive dressing to help absorb discharge.

**Lymphangiomas (Cystic Hygromas)**

These are malformations within the lymphatic system that result in diffuse swelling and may increase in size with upper respiratory infections.

Larger hygromas are more likely to need temporary tracheotomy to prevent airway obstruction.

May involve all major nerves and vasculature within the neck and oral cavity.

Nonsurgical treatment is an option for macrocystic lesions using injection sclerotherapy.

Complete excision may be impossible.

Recurrence is common and should be discussed at initial surgical consultation.

**Surgical Technique**

Surgery is performed under general anesthesia. Avoid muscle relaxants.

Consider airway management.

Place a shoulder roll to extend the neck.

Inject the skin incision with lidocaine 1% with epinephrine 1:100,000. Avoid injecting into the hygroma.

After incising skin and subcutaneous tissue, raise subplatysmal flaps.

Dissection of the lesion is usually started in the inferior aspect, identifying normal landmark structures before dissection into the more cystic areas.

Avoid entering into the cystic mass. The wall of the cyst can frequently be confused with various structures within the neck, resulting in incomplete removal or injury to other structures.

Nerve stimulation at 0.5 mA will help in identification of nerves.

After complete resection, the wound should be vigorously irrigated and aggressively drained. Do not remove the drain prematurely because drain output often continues for 5 to 7 days.

Long-term follow-up is important because recurrence is the norm. Consider injection sclerotherapy for recurrence of macrocystic lesions.

If the aerodigestive tract is entered, place a nasogastic tube and repair the pharynx, leaving the patient NPO for 2 or 3 days. Obtain a swallow study after that time period, and if no extravasation, the patient may be started on oral feeding.
Chapter 20  Noncancer Surgery of the Neck

◆ Open Neck Biopsy

◆ Indicated for establishing the diagnosis in the following types of neck masses:
  ◦ Infectious
  ◦ Inflammatory
  ◦ Malignant

◆ Allows for flow cytometry studies, which may not be available with fine-needle aspiration (FNA) biopsy

◆ Rule out nontuberculous or other contact infections that can cause cervical adenopathy

Surgical Technique

◆ Preoperative inspection of the upper aerodigestive tract should be performed to rule out malignant etiology for the neck mass. FNA is helpful in cooperative patients.

◆ Surgery may be performed under general or local anesthesia depending on patient cooperation.

◆ Nonparalytic anesthetic technique is used to facilitate cranial nerve identification.

◆ A shoulder roll is placed to extend the neck slightly.

◆ The skin is marked in a line of relaxed skin tension prior to cutting or injecting local anesthetic. One important consideration is to create an incision that would facilitate later neck dissection if cancer were diagnosed.

◆ Send specimen to pathology “fresh” (i.e., not informalin solution) for possible lymphoma workup/flow cytometry. Routine pathologic analysis, aerobic and anaerobic cultures, acid-fast bacillus stains and cultures, and fungal stains and cultures are ordered when indicated.

◆ If atypical mycobacterial infection is suspected, the area of skin immediately overlying the mass should be excised en bloc with the specimen.

◆ Irrigate wound vigorously after lesion is removed.

◆ Drainage of wound should be considered for larger fields. The incision can then be closed in layers using absorbable suture.

◆ Lipomas

◆ May occur in any location within the neck, but most commonly found in posterior neck

◆ Indications for removal include cosmetic or compressive reasons.

Surgical Technique

◆ Generally removed under general anesthesia

◆ Posterior neck lipomas require prone positioning. In such cases, the patient is intubated on the hospital gurney, then rotated onto the operative table.
Outline incision in a line of relaxed skin tension prior to injection of local anesthetic.

Subcutaneous tissue is entered, the capsule is exposed, and skin flaps are locally elevated enough to allow removal of the lipoma.

Circumferentially dissect lipoma with electrocautery. Apply gentle traction using an Allis or Babcock clamp.

Posterior neck muscles are often in deep margin of dissection. Avoid dissection into or cautery of the muscle to prevent postoperative pain and dysfunction.

Adequately drain wound with a Penrose or suction drain for 24 hours. Pressure dressings in the neck are very difficult to apply and are often insufficient.

Absorbable suture is used to close the dermis, and staples are used for the skin in the posterior neck.

**Branchial Cleft Anomalies**

Result from persistence of the branchial system of development in the fetus

- **Cysts** Epithelial capsule without connection to surface epithelium or mucosa
- **Sinus tracts** Connect with the surface or the mucosa
- **Fistulae** Connect with surface epithelium and mucosal layers

A barium swallow may delineate a fistulous tract. The tract of the cyst will be deep to the structures associated with its own derivation and superficial to those structures associated with lower clefts (Table 20–1).

**Surgical Technique**

- Surgery is performed under general anesthesia, avoiding muscle relaxants to allow use of facial nerve monitoring.
- Place a shoulder roll to extend the neck.
- Design incision in a line of relaxed skin tension and excise any cutaneous sinus

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<th>Table 20–1 Course of Branchial Cleft Cysts</th>
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tract. A lacrimal probe inserted into the sinus tract provides an excellent landmark to ensure complete removal of the tract. Avoid injecting methylene blue or other agents into the tract.

- Inject incision with lidocaine 1% with epinephrine 1:100,000.
- For first branchial cleft anomalies, it is important to identify the facial nerve via nerve monitoring or superficial parotidectomy prior to excising any tract. The tract in first branchial cleft cysts may go medial or lateral to the facial nerve.
- If a duplication of the external auditory canal is encountered, it must be fully dissected and removed to prevent recurrence.
- “Stairstep” the incision 2 to 3 cm apart to provide adequate visualization.
- The wound is irrigated and closed in layers.
- A small drain, such as a rubber band or Penrose drain, can be placed and removed on the first postoperative day.
- If the aerodigestive tract is entered, a nasogastric tube is placed for postoperative feedings for 3 days. A swallow study is used to guide cessation of nothing by mouth (nil per os, NPO) status.
Surgery for Congenital Ear Malformations

Robert A. Jahrsdoerfer and Bradley W. Kesser

Classification

Congenital malformations of the ear can be broadly classified into two categories:

- **Minor malformations**  Problem is limited to the middle ear
- **Major malformations**  Atresia or stenosis of the external ear canal. Congenital aural atresia means the external ear canal has failed to develop. Congenital stenosis refers to partial development of the external ear canal. Both are usually associated with microtia, although on occasion the external ear may be well formed.

Hearing Evaluation

- Auditory brainstem response (ABR) testing is mandated in a newborn with microtia/atresia. Otoacoustic emissions may be of use in unilateral atresia if the contralateral ear is normal.
- The side with the better cochlear reserve is operated upon to achieve the best postoperative hearing result.
- If there is any doubt concerning hearing, a bone conduction hearing aid should be placed as early as possible.

Preoperative Considerations

Timing of Surgery

- Once a child with unilateral or bilateral atresia has been determined to have one normal hearing ear or has been aided for hearing loss, he or she is allowed to
mature until 5 years of age. At that time, consultation should be had with a plastic surgeon and an otologic surgeon.

Prior to age 5 there is often a degree of immaturity that makes routine postoperative care problematical, often requiring the use of sedation or forcible restraint.

**Preoperative Testing**

- Audiologic testing should be repeated prior to surgery.
- A high-resolution computed tomography (CT) scan of the temporal bone in the 30-degree axial and 105-degree coronal planes should be obtained. The appearance of the CT scan will be the primary determinant of the patient’s candidacy for atresia surgery. The scan is again reviewed on the day of surgery with emphasis placed on the course of the facial nerve, slope of the tegmen, and depth of the middle ear from the lateral aspect of the skull.

**Special Surgical Considerations**

**Minor Malformations**

- Minor malformations typically involve the stapes/oval window/facial nerve axis. The auricle and external ear canal are normal in appearance, or almost so, and the tympanic membrane can be identified.
- When an absent oval window is found at surgery, the choices available to the surgeon are to terminate the operation or to attempt hearing restoration by creating a vestibulotomy. If the latter approach is chosen, there should be a defined oval window area that can then be targeted for drilling, as well as mature ossicular development to enable placement of a prosthesis.
- Once a vestibulotomy is drilled, the opening should be covered with temporalis fascia or other appropriate soft tissue seal. The distance between the new oval window and the ossicle may vary greatly. A wide assortment of prosthesis lengths should be available.
- A bare facial nerve will not infrequently be found to overlie the area where the new oval window should be drilled. In malformations limited to the middle ear, it is not possible to transpose the facial nerve as it is in atresia surgery. A decision must be made to drill above or below the bare facial nerve. Again, a well-defined oval window area helps in this decision. Lacking this, drilling may begin superior to the nerve using a saucerizing technique. If the vestibule is not encountered at a depth of 2 mm, the procedure is terminated because there is a heightened risk of sensorineural hearing loss from surgical violation of the membranous labyrinth.
- If a bare facial nerve obscures the oval window superiorly, a promontorial window may be drilled according to Plester. The promontorial bone should be saucerized down to an intact endosteal membrane. Disruption of the endosteal membrane carries a greater chance of nerve loss from cochlear injury. A prosthesis can be inserted between the endosteal membrane and the malleus handle, or the tympanic membrane if the handle is unfavorable.
- The most important aspect in exploring the middle ear of a patient with a conductive hearing loss is an awareness that one may be dealing with a congenital
malformation. This awareness must include the possibility of finding a bare and displaced facial nerve. Failure to recognize this possibility places the patient at a huge risk of facial nerve injury.

◆ Congenital primary incus fixation is rare. Fixation of the malleus in the epitympanum is not. There are two surgical methods to correct malleus head fixation:
  ○ Remove the malleus head and incus, and place an incus strut from the malleus handle to the stapes.
  ○ Drill away the bony attachment in the epitympanum, and interpose Silastic® sheeting as a barrier to bony refixation.

◆ Ossicular fixation may also be attributable to a malleus bar. This is a term coined by Nomura² to describe a bar of bone running from the malleus neck to the posterior bony annulus. This bony bar will be ~1 mm in thickness and firmly fixes the malleus in place, producing a conductive hearing loss. The chorda tympani nerve frequently runs in a bony groove in the bar and must be considered when drilling away the bar. Freeing the ossicular chain from the malleus bar will usually correct the conductive hearing loss, but not always. If the chain remains fixed, one must search for additional sites of fixation. It is our preference that any suspected congenital middle ear malformation be approached through a postauricular incision. The ossicular anomaly, commonly the stapes/oval window/facial nerve complex, is often concealed by overhanging bone. As much as 3 to 4 mm of bony overhang may need to be drilled away to access the area of concern.

Major Malformations (Congenital Aural Atresia)

◆ Atresia repair should follow microtia repair. The external ear reconstruction should be done by a plastic surgeon or facial plastic surgeon experienced with this challenging surgery. Rib graft reconstruction is best performed when the rib cage has reached satisfactory growth to enable harvesting an amount of cartilage adequate for sculpting into an ear framework. This usually occurs between 6 and 8 years of age for those children with unilateral atresia. In bilateral atresia cases, we will encourage the reconstructive surgeon to operate earlier, thereby allowing the otologic surgeon to do the atresia repair at least in one ear prior to starting school.

◆ If an alloplastic implant has been chosen for the external ear reconstruction, we recommend atresia surgery before the microtia repair. The child is a noncandidate for atresia repair. Silastic or polyethylene implants may do well until they are exposed, at which time they invariably become infected and extrude. Our major concern is that the child may need revision surgery after an alloplastic implant has been placed, in which case the implant is at great risk for exposure.

◆ It is our preference that the reconstructive surgeon completely finish the microtia repair prior to atresia surgery. If this is not possible, then the earliest the otologic surgeon should operate is after the rib cartilage has been implanted and the lobe transposed. We prefer to wait 4 to 6 months after the plastic surgeon has finished to begin operating for atresia.

◆ In cases of bilateral atresia, the better appearing, or higher graded, ear should be operated first. In patients with bilateral atresia, the initial restoration of hearing is a dramatic event. In unilateral atresia with normal hearing in the contralateral ear,
restoration of hearing results in a subtle but meaningful response. Discrimination is improved immediately, and sound localization, though less predictable, usually improves over time.

**Surgical Technique**

- The patient is placed on the operating room table in a slightly reverse Trendelenburg position. A swath of hair ~0.5 to 1 inch in width is shaved from above the ear. Local anesthesia is infiltrated in the postauricular crease, and electrodes are placed for facial nerve monitoring. The anesthesiologist is requested to avoid paralytic agents unless they are needed for induction.
- A postauricular approach is used routinely. Temporalis fascia is harvested and allowed to dry. The periosteum overlying the mastoid bone is incised and elevated. A cuff of periosteum is preserved at the level of the glenoid fossa for future use.
- If a tympanic bone remnant is identified, drilling should begin there. Most of the time a tympanic bone remnant is absent, and drilling therefore commences in the cribiform area.
- The direction of drilling should be a straight approach to the middle ear. Do not indiscriminately drill out the mastoid. The mastoid approach may soothe the anxiety of an insecure surgeon but does little good for the patient. The degree of mastoid pneumatization is noted. Atretic bone is usually found anteriorly and should be tracked medially. Do not pursue mastoid air cells, as this route will lead into the mastoid antrum far posterior to where the surgeon desires to be.
- At a depth of 1.5 cm, the atretic plate is usually encountered. Our definition of atretic plate is that layer of atretic bone contiguous to the middle ear. If the atretic plate has not been identified at a depth of 2 cm, the surgeon should backtrack in the dissection because the middle ear may have been bypassed.
- It is imperative to maintain a vigil for the facial nerve while drilling. In ~25% of patients the facial nerve will make a sharp turn at the second genu to cross the middle ear in atretic bone and exit into the glenoid fossa. What is not generally appreciated is that the nerve ascends in its course through the middle ear. The facial nerve may be 4 mm more lateral at the round window level than at the oval window. In this situation the nerve is still encased in atretic bone and is at risk of being injured by drilling before the middle ear is ever reached (Fig. 21–1).
- The atretic bone is thinned with a diamond bur and carefully picked away to reveal the contents of the middle ear. In complete atresia where there is no tympanic membrane remnant, the malleus handle will be absent. The ossicular mass is attached to the atretic plate at the level of the malleus neck by either bone or periosteum. If there is a bony connection between the malleus neck and the atretic plate, the ossicular mass will be firmly fixed. A periosteal attachment will allow some movement of the ossicles. A floppy ossicular chain indicates a failure of the fused incus–malleus to connect to a stapes. A firmly immobile ossicular mass indicates fixation at least at the level of the atretic plate, although the ossicles may be fixed at more than one site.
- The middle ear findings will include an incus–malleus complex that is usually fused, an incus long arm that is often foreshortened and sometimes vertical, an
incudostapedial joint that has failed to develop and that may form a solid bony union between the two ossicles, and a stapes of variable development. There is a 4% incidence of a fixed stapes from failure of the footplate to differentiate. A chorda tympani nerve is seen in fewer than 50% of the cases, and when present, will typically be situated far inferior in the middle ear. In this location the chorda is difficult to save as it courses through the atretic bone, which must be drilled away to complete the operation. The facial nerve may be bare above the oval window and as previously mentioned is significantly displaced in 25% of the cases.

- Ideally, the best possible condition in which to find the ossicles is to have an intact ossicular chain, although malformed, but which moves as a unit. In ~20% of the cases, the ossicular chain will be discontinuous, requiring ossicular chain reconstruction. Total ossicular replacement prostheses (TORPs) and partial ossicular replacement prostheses (PORPs) of the surgeon’s preference are suitable in reconstructing the ossicular chain.

- Bone peripheral to the ossicular chain is drilled away to center the ossicles in the approximate middle of the new tympanic membrane. The bony bridge connecting the malleus neck to the atretic plate is saved until last. It is then thinned by drilling with a diamond bur and then carefully drilled away at slow revolutions, or vaporized with a laser. Once free, the ossicular chain is highly mobile, and the inner ear is vulnerable to injury from overzealous ossicular manipulation or damage from the drill.

- One must be diligent in removing bone dust from the middle ear, particularly from the oval window niche and the undersurface of the incus–malleus complex. Failure
to do so may result in bony bridging with fixation of the ossicular chain and a large postoperative conductive hearing loss.

◆ At this point in the operation, the skin graft may be harvested. The ipsilateral arm is extracted from beneath the drapes and placed on an armboard. The arm is bent cephalad so that the medial aspect of the upper arm is facing upward. After the arm is prepped and draped, mineral oil is swabbed on the skin to lubricate the surface, and a marking pencil is used to outline the length of the graft. The size of the graft, ~5 × 7 cm, allows for harvesting of a second skin graft, if needed, from the upper arm. On occasion, the initial graft will be too thick, or too thin, or may have shredded. The initial graft is routinely taken higher on the arm, leaving a lower area closer to the elbow where a second graft can be harvested, if required. We use a Zimmer air dermatome with the 2 inch template set at a thickness of 0.006 inch. If the harvested graft is too thick, it will tend to curl at the edges and be difficult to work with. If the graft is too thin, it will tend to break down postoperatively and will withstand environmental abuse poorly (e.g., swimming, hearing aid molds, routine cleaning). The skin graft donor site is covered with scarlet red dressing and Telfa® and wrapped with Kling®. The arm is then repositioned at the patient's side. The split-thickness skin graft is rinsed in lactated Ringer's solution to remove any blood clots. It is placed on a dermacarrier and cut to size using a sharp no. 15 blade. A Teflon® block is used to fix the graft by external pressure while the cut is made along the edge of the block with the knife.

◆ The split-thickness skin graft will usually have one edge thinner than the other. This side should be used at the level of the tympanic membrane to cover the fascia graft, and the thicker edge should be used at the level of the meatus.

◆ Prior to placement of the fascia graft, two important steps are taken:
  ◆ The area of the new meatus is injected with lidocaine 1% with epinephrine 1:50,000.
  ◆ The anesthesiologist is asked to lower the expired partial pressure of oxygen to 25% or less. Injecting the skin and soft tissue in the area of the new meatus at this stage will help to ensure a relatively bloodless field when the new meatus is created.

◆ We have found that when the partial pressure of expired oxygen is 30% or greater, there will be a differential release of oxygen into the middle ear; this will cause ballooning of the graft. This is not a problem in routine tympanic membrane perforation repair because there is usually some rigidity to the remaining tympanic membrane, which will hold the graft in place. However, when one is dealing with a total tympanic membrane repair or creating a new tympanic membrane, the problem is magnified. If the new tympanic membrane is elevated off the fused incus–malleus complex by increased gas pressure, it may not reattach. Should this happen, the final position of the drum will be lateral to the ossicles, and the postoperative hearing result will be poor.

◆ The choice of anesthetic agent is important. Isoflurane is the agent of choice in preference to desflurane and sevoflurane, which produce a higher partial pressure in the middle ear.

◆ A temporalis fascia graft is positioned in the new ear canal as a lateral tympanic membrane graft. The edges of the fascia graft are reflected onto the new bony
external ear canal for ~2 to 3 mm. Special grooves drilled into the bony external ear canal to accommodate the fascia graft are not necessary.

- The split-thickness skin graft is shaped as previously mentioned and is now inserted into the external ear canal to line the bare bone of the new canal. The notched skin tabs are reflected onto the fascia graft to provide a second epithelial cover. The tabs should completely cover the fascia.

- A Silastic button is fashioned, cut to size, and strategically placed in the ear canal to cover the tympanic membrane. The button is used to discourage blunting of the tympanic membrane and provide a sulcus anteriorly and inferiorly.

- Four or five dry Merocel wicks are inserted and hydrated with an eardrop preparation. The lateral edges of the split-thickness skin graft are folded over the Merocel packing, and attention is turned to the meatus.

- A U-shaped pedicle flap hinged at the tragus is outlined and the skin portion raised. The underlying soft tissue is sharply cored with a no. 11 blade. This provides access to the new canal, which is now situated directly medial. The skin pedicle flap is swung down into the lateral external ear canal and sutured to a cuff of periosteum, as previously mentioned. This maneuver provides excellent skin coverage to the anterior portion of the soft tissue part of the new canal. This step also helps prevent postoperative meatal stenosis.

- In approximately half of atresia cases, the external ear will need to be repositioned to better align the new meatus and the new ear canal. To accomplish this, subcutaneous dissection of the external ear is necessary. The plane of dissection should be lateral to the parotid capsule to avoid a potential postoperative salivary fistula. Because the external ear is not yet tethered by an ear canal, the auricle can be moved as much as 3 cm in a posterosuperior direction. Once the location of the external ear is finalized, it is fixed in place with subcutaneous sutures. Thereafter all work is done directly through the new meatus. The edges of the split-thickness skin graft are identified, brought to the edges of the new meatus, and sutured in place. Additional Merocel® wick packing is inserted as needed, and a mastoid dressing is applied.

◆ **Postoperative Care**

- An overnight stay in the hospital is required. The following morning the head dressing and arm dressing are removed with the exception of the scarlet red patch, which is allowed to remain in place until it spontaneously falls off in about 2 weeks.

- Postoperative visits are scheduled at 1 week and at 1 month. At 1 week, all Merocel packing and the Silastic button are removed. An antibiotic/steroid eardrop preparation is prescribed for 1 week. The new external ear canal is thereafter left open to the air.

- By the 1 month postoperative visit, the split-thickness skin graft will have desquamated, leaving a crust of skin in the new ear canal and over the tympanic membrane. This is gently removed in the office, revealing healthy pink skin beneath. A postoperative audiogram is obtained at this point.
Once healing has stabilized, long-term routine care appointments can be made every 6 to 12 months. Because the new ear canal skin does not migrate as in normal ear canals, routine cleaning will be required indefinitely.

**Risks and Complications**

The two greatest risks to the patient in aural atresia surgery are facial nerve injury and sensorineural hearing loss.

**Facial Nerve Injury**

- As previously mentioned, the facial nerve is significantly displaced in 25 to 30% of surgical cases.
- For the surgeon inexperienced in atresia repair, the greatest chance of facial nerve injury occurs from drilling within the temporal bone.
- For experienced surgeons, the greatest risk to the nerve is extratemporally, where the nerve has exited the temporal bone and runs in soft tissue on the lateral surface of the mastoid.
- Routine imaging will not identify the nerve once it leaves the temporal bone. Preoperatively, one must carefully study the CT image of the temporal bone and identify the facial nerve with a high degree of certainty. If the nerve cannot be positively identified, one should search for thin soft tissue containing bony passages from the middle ear to the lateral surface of the mastoid. These uneven lines may represent a displaced facial nerve.
- If the facial nerve cannot be positively tracked on the CT scan, or is lost in soft tissue upon exiting the temporal bone, then these conditions justify canceling the surgery.

**Sensorineural Hearing Loss**

- Severe sensorineural hearing loss occurs in ~2 to 3% of patients undergoing atresia surgery.
- Sensorineural hearing loss limited to the high frequencies may occur in up to 15% of patients. In this latter group, low and midrange frequencies are usually improved, and the speech reception threshold and discrimination scores are better.
- The goal of the operation is to improve hearing. This is only possible by mobilizing the ossicular chain. Once all bony bridges fixing the ossicular mass have been removed, the ossicular chain becomes highly mobile. At this junction the risk of acoustic injury from drilling or ossicular manipulation is paramount. Even without brushing the ossicles with the drill, there is a transfer of acoustic energy to the inner ear from drilling on the atretic bone or on the atretic plate itself.

**Mental Stenosis**

- Making the new meatus at least 1½ times the size of a normal ear canal opening will help control postoperative stenosis. The use of a tragal based pedicle flap also
helps maintain patency. Lastly, if early meatal narrowing is apparent at 1 month, subcutaneous injections of triamcinolone are started.

New Bone Growth

- A late complication producing stenosis of the external ear canal is new bone growth. This typically occurs 3 to 10 years after the initial atresia surgery and occurs more frequently in younger children than in teenagers. The problem with new bone growth is twofold:
  - It can cause bony obstruction of the ear canal, preventing adequate debridement of the skin.
  - It can encroach upon the tympanic membrane, causing a progressive conductive hearing loss. This condition is correctible by revision surgery.

References

The most important aspect of stapes surgery is careful preoperative selection of surgical candidates, meticulous hemostasis, and careful identification of anatomical landmarks.

◆ Preoperative Considerations

Tuning Fork Testing

◆ The otolaryngologist must use tuning forks to confirm the results of audiologic testing prior to surgery. Both the 512 and 1024 Hz forks are used.

◆ The 512 Hz tuning fork gives a negative result if the air–bone gap is greater than 25 dB.

◆ The 1024 Hz tuning fork is negative if the air–bone gap is greater than 30 dB.

◆ The 256 Hz fork can be less accurate because it tests low frequencies, which are the same as the ambient noise in an office. More importantly, the 256 Hz fork gives a negative result if the air–bone gap is greater than only 15 dB. A 15 dB air–bone gap should never be an indication for a surgical procedure to improve hearing. Stapedectomy should be performed when the air–bone gap is greater than 25 dB.

Sensorineural Hearing Loss

◆ Additional underlying sensorineural hearing loss should be considered in selecting patients for stapes surgery. If correction of the conductive component does not
bring hearing up to a normal or mild hearing loss range, the patient should be counseled regarding the need for amplification even after successful stapedectomy.

- In patients with severe to profound mixed hearing loss, successful stapedectomy may enable the patient to use a conventional hearing aid more effectively by reducing the gain required.

**Meniere’s Disease**

- When a patient has Meniere’s disease, there is swelling of the endolymphatic space, or endolymphatic hydrops. During stapedectomy, the saccule may be punctured, which can result in profound sensorineural hearing loss. In rare instances, when a patient has both otosclerosis and Meniere’s disease, I choose not to operate and instead recommend a hearing aid.

**External Canal Stenosis/Exostoses**

- If the patient has a small ear canal or exostoses, the operation should be staged. The canalplasty should be done first, enlarging the canal and allowing it to heal. Three to 6 months later, the stapedectomy is performed.

**Surgical Technique**

- Stapes surgery can be performed under general or local anesthesia with mild sedation. In a cooperative adult patient, it is better to perform the stapedectomy under local anesthesia with mild sedation. This allows for subjective evaluation of hearing result during surgery and detection of dizziness secondary to a long prosthesis projecting into the vestibule.

- The use of a speculum holder may be helpful and is optional.

- To achieve good hemostasis, inject 1 to 2% Xylocaine® (lidocaine) with epinephrine 1:100,000. Injection should start with a 25-gauge needle in four quadrants at the junction of the cartilaginous and bony canal. Subsequently, a 30-gauge needle is used to infiltrate the tympanomeatal flap.

- The incision should not be made for at least 5 minutes after injection of the local anesthetic with epinephrine to get the maximum hemostatic effect.

- When turning a tympanomeatal flap, it is important not to make the flap too short (8 mm from the fibrous anulus is generally recommended) because it usually retracts and results in a marginal perforation.

- When approaching the fibrous anulus, it is important that you use a small round knife to lift up the anulus. Sometimes it is also helpful to use a Rosen needle to tease off a small area of the fibrous anulus to enter the middle ear. After a small opening is made, a Buckingham duckbill or anulus elevator is used to elevate the rest of the fibrous anulus to raise the tympanomeatal flap. Anterior elevation of the flap should be continued until the malleus handle is visualized.
◆ If a small marginal perforation occurs that can be repaired with a small piece of adipose tissue from the earlobe, stapedectomy can proceed. If the perforation is larger, it is better to perform the tympanoplasty with fascia graft and abort the stapedectomy.

◆ The chorda tympani nerve can be displaced superiorly or inferiorly for exposure, but one should not stretch it.

◆ The posterosuperior bony canal is curetted to visualize the pyramidal process and tympanic facial nerve.

◆ The incudostapedial joint is then divided using a sharp hook or joint knife.

◆ Palpate the malleus to check for malleus, incus, and stapes mobility. If the malleus is fixed, the head of the malleus needs to be sectioned along with the stapedectomy, and the patient will require a malleus–oval window prosthesis.

◆ One can do a stapedotomy or partial stapedectomy or remove the entire footplate. It is the surgeon’s choice based on experience. A tissue graft is required to seal the oval window if partial or total stapedectomy is planned. This should be harvested and ready to use prior to stapes manipulation.

◆ A control hole is created in the stapes footplate using a straight pick in the case of partial or total stapedectomy. This allows detection of a perilymph gusher, requiring a firm tissue seal.

◆ Removal of the stapes superstructure begins with division of the stapedial tendon close to the pyramidal process. The superstructure can be down-fractured anteroinferiorly using a curved pick, then removed.

◆ The prosthesis length is determined prior to creating a stapedotomy or footplate removal using standard measuring sticks (3.5, 4.0, and 4.5 mm). Depending on the prosthesis used, the distance between the footplate and medial or lateral surface of the incus long process is measured. The average length of an incus–oval window prosthesis is 4.0 to 4.25 mm. The average length of a malleus–oval window prosthesis is 5.5 mm.

◆ A stapedotomy is performed using a low-speed drill or laser. Footplate removal is performed using a combination of sharp-angled picks.

◆ If partial or total stapedectomy is planned, the tissue graft is laid over the oval window prior to prosthesis placement.

◆ Crimping the prosthesis over the incus long process has to be done so that the wire is snug around the long process of the incus without fracturing it. To maneuver the wire, it is preferable to use a House strut guide. Crimping is performed using a crimper and alligator. The crimping maneuver consists of the following three steps:

   ◇ The posterior arm is pushed forward (Fig. 22–1A).
   ◇ The forceps is rotated (Fig. 22–1B).
   ◇ The crimping is completed (Fig. 22–1C).

◆ Before turning the tympanomeatal flap back, always check for the ossicular mobility and look for the round window reflex, if possible. One has to ascertain there is no perilymph leak before placing the tympanomeatal flap back.
Figure 22–1 Crimping the stapes wire. (A) Push posterior arm of the forceps forward. (B) Rotate forceps. (C) Complete the crimp. (From Johnson JT, Blitzer A, Ossoff RH, Thomas JR. Instructional Courses, Vol. 3. St. Louis, MO: Mosby Year Book: 1990. Reprinted with permission.)

◆ Pearls and Pitfalls

◆ When performing a stapedectomy, it is important to position the patient properly. To see the protympanum anteriorly, raise the table and rotate the patient away from the surgeon. To view posteriorly, lower the table and rotate the patient toward the surgeon. To see the attic superiorly, lower the head of the patient. To see the hypotympanum, raise the head of the patient.

◆ If the patient has a mildly dehiscent facial nerve, the stapedectomy can be performed by bending the wire (Fig. 22–2). If the facial nerve is significantly dehiscent and prolapsed into the oval window, the risks of postoperative facial paralysis and residual conductive hearing loss are significant (Fig. 22–3). If this is encountered at surgery, surgery should be aborted, and the patient should be offered a hearing aid instead.

◆ If there is a small piece of footplate that is lost, and if there is some bleeding around the footplate, the blood flowing into the vestibule sometimes floats out the small piece of footplate. Do not go into the vestibule to look for the footplate lest you cause damage to the saccule or the utricle.
Figure 22–2 Mildly dehiscent facial nerve. (From Johnson JT, Blitzer A, Ossoff RH, Thomas JR. Instructional Courses, Vol. 3. St. Louis, MO: Mosby Year Book: 1990. Reprinted with permission.)

Figure 22–3 Significantly dehiscent facial nerve in temporal bone section.
When crimping the stapes wire, make sure that it is crimped all the way around so that it does not fall off. **Fig. 22–4A–C** shows three crimped stapes wires. The wire in **Fig. 22–4A** is perfectly crimped. The wire in **Fig. 22–4B** is acceptable because it will not fall off. The wire in **Fig. 22–4C**, however, is unacceptable because with vibrations and movement, it will fall off.

When removing a floating footplate, a common maneuver is to drill a small hole next to the footplate on the promontory side, insert a small 0.3 mm hook into the hole, and tilt the footplate out. However, it is usually not necessary to drill a hole. If the surgeon is skillful, it is possible to slip a 0.3 mm hook parallel between the footplate and the fibrous anulus, which suspends it, then tilt the footplate out. An argon laser can be used to vaporize the footplate partially or completely.

Immediate vertigo after stapedectomy is the result of perilymph loss from suctioning. Vertigo can also be caused by leakage of perilymph fluid because the tissue plug does not give a perfect fit. Because of the shape of the oval window niche, a large tissue plug may give the appearance from the surgeon’s view of sealing the oval window, even though there are small leaks medial to the plug that the surgeon cannot see from his or her vantage. If in doubt, a tissue plug that is too small is better, followed by plugging all the remaining fistulae with smaller pieces of tissues until a tight seal is achieved. Ideally, a single snug piece of tissue plug, fitting just right, should be used.

**Malleus–Oval Window Prosthesis**

The malleus–oval window prosthesis is a more difficult operation than the incus–oval window prosthesis. Whereas the average length of an incus–oval window prosthesis is 4.0 mm, the average length of the malleus–oval window prosthesis is 5.5 mm.

First, the prosthesis, shaped like a paper clip, is hung on the malleus handle. At this point, the surgeon does not need to place the other end of the prosthesis over the oval window (**Fig. 22–5A–C**). Next, the wire is held with a smooth alligator forceps, while a knot is tied using a 1 mm hook. It is important that only smooth alligator forceps be used for handling the wire. Although the serrated alligator forceps are good for handling tissue, the wire can get caught by the serrations and
make it difficult to release the wire. Because it is impossible to tie the wire perfectly tight, tie the knot as tight as possible on a thinner portion of the malleus handle, then slide the prosthesis wire to a thicker section of the malleus handle, giving a snug fit. Subsequently, the wire is bent to fit the other end into the oval window.

To minimize the extrusion of the wire, the perichondrium of the malleus handle should be elevated together with the tympanic membrane. Hence, the wire will be sitting on the bone, and lateral to it are the periosteum of the malleus and the tympanic membrane. If the tympanic membrane is atrophic, a small piece of fascia should be sandwiched between the wire and the tympanic membrane.

Figure 22–5 Malleus-oval window prosthesis. (A) Hang prosthesis on the malleus. (B) Tie knot with a hook. (C) Slide prosthesis wire to thicker section of bone to give a snug fit. (From Johnson JT, Blitzer A, Ossoff RH, Thomas JR. Instructional Courses, Vol. 3. St. Louis, MO: Mosby Year Book: 1990. Reprinted with permission.)
Chronic Ear Surgery

K. J. Lee

◆ General Principles

◆ One has to weigh carefully the pros and cons of a given situation when determining whether surgery is safer than leaving the problem unattended. A case in point is a 75-year-old nonswimmer with a small anterior dry perforation with mild recurrent infection once a year, successfully treated each time with antibiotic eardrops with or without systemic antibiotics. The audiogram shows a 10 dB air–bone gap. Obviously, there are many other scenarios. Although a larger perforation without cholesteatoma can potentially lead to vertigo, facial nerve paralysis, meningitis, and brain abscess, what is the likelihood? One has to balance that probability with the risk of surgical complications prior to embarking on surgery.

◆ A patient with a large perforation or a posterolateral quadrant perforation without cholesteatoma or not infested with squamous debris can be considered for tympanoplasty without mastoidectomy.

◆ A patient with a perforation with frequently recurrent suppuration with or without cholesteatoma or squamous debris infestation can be considered for one of the following variations of tympanomastoid surgery:

  ◦ Complete simple mastoidectomy with tympanoplasty (reserved for patients with minimal mastoid disease without cholesteatoma)

  ◦ Canal wall up facial recess mastoidectomy with tympanoplasty

  ◦ Canal wall down mastoidectomy with tympanoplasty

  ◦ There are pros and cons to each of these categories. The canal wall up mastoidectomy works well for certain surgeons but has higher failure rates in the hands of inexperienced surgeons. It is generally agreed that a canal wall up mastoidectomy has a slightly higher incidence of recurrent cholesteatoma.
The canal wall down approach allows the surgeon to more completely eradicate disease. One of the criticisms is that it leaves behind a large cavity, leading to the need for frequent cavity care.

The author has combined a method of meticulously enlarging the meatus and canal as well as reducing the cavity size in the canal wall down technique. This technique eliminates the requirement for frequent cavity care.

When performing myringoplasty or tympanoplasty, one can place the graft laterally, medially, or a combination of the two.

In placing the graft laterally, one has to be sure to deepithelialize the remaining tympanic membrane so as not to bury squamous debris. One has to pack the graft well to avoid anterior sulcus blunting or subsequent lateral displacement of the graft causing poor ossicular contact. To avoid anterior blunting or lateral displacement anteriorly, avoid having the anterior edge of the graft “climb” the anterior canal wall. The anterior edge should be just snug up to the anterior sulcus. Any anterior canal bony bulge should be drilled down. In drilling anteriorly, avoid violating the temporomandibular joint (TMJ), which is situated approximately halfway down and midway between the superior and inferior aspect of the anterior bony canal. Diamond burs should be used when approaching the TMJ. The author uses the medial/underlay grafting technique routinely except for cases of isolated small anterior perforations. Placing the graft medially for a small anterior perforation repair can lead to the graft’s being displaced medially into the eustachian tube orifice in the protympanum.

Eliminating the conductive hearing loss is a function of eliminating middle ear disease, preserving mucosa in the middle ear, and restoring aeration in the middle ear, allowing a phase difference between the oval and round windows.

A patient with a type III tympanoplasty without an ossicular replacement prosthesis, who has a well-aerated middle ear, can have an air–bone gap of no more than 10 to 15 dB. Hence, in performing ossicular reconstruction, one needs to pay attention to restoring middle ear aeration.

A type IV tympanoplasty (in which the graft is on the footplate) with a pocket of air over the round window niche can have an air–bone gap of no more than 30 dB. It is ideal to have a “columella” reconstruction, to convert a type IV into a type III tympanoplasty.

The use of Gelfilm® helps to prevent adhesions and, in certain cases, promulgates the regeneration of middle ear mucosa. An atelectatic ear will always have poor hearing.

Special Considerations for Canal Wall Down Mastoidectomy

Common pitfalls of canal wall down mastoidectomy include the following:

Postoperative meatus or canal may be too small.
Too little skin grafting to help epithelialization
The mastoid cavity is too big relative to the size of the meatus.
Packing may cause more granulation tissue, and when removed leads to more scar tissue and “weeping.”
These problems can be solved by creating a large meatus and a large canal and by using a regional fascia flap that is well vascularized. The patient will heal faster. A muscle graft can be used to obliterate the mastoid cavity partially, thus minimizing the size of the cavity if all cholesteatoma and squamous debris have been removed.

A criticism of using a muscle graft to minimize the size of the cavity is that the muscle used to obliterate the cavity could bury cholesteatoma. The solution is simple: in cases with extensive cholesteatoma, the musculoplasty should not be performed. One cannot bury cholesteatoma; the muscle can be placed to minimize the cavity only where there is no residual cholesteatoma. This usually does not pose a problem because most cholesteatoma is located in the antrum and superiorly, whereas the musculoplasty is placed inferiorly to fill in the mastoid tip region. In rare cases in which the cholesteatoma is left inferiorly, the musculoplasty should not be performed.

The second criticism of the musculoplasty technique is that the muscle atrophies, thereby making it impossible to completely obliterate the bony cavity. The goal of musculoplasty, however, is to convert the cavity and the ear canal into more of a cylindrical, instead of an hourglass, shape to shrink the cavity, not to obliterate it entirely (Fig. 23–1A,B).

Potential problems for mastoidectomy are meatal stenosis, canal stenosis, and projecting bony buttresses (grooves and corners that hide disease; these should be smoothed down). Too much exposed mucosa leads to weeping, and these raw areas should be grafted with temporalis fascia.

**Special Considerations for Mastoidectomy**

In mastoidectomy, problematic areas include the following:

- Epitympanic space
- Zygomatic root air cells
- Sino-dural angle
- Perilabyrinthine cells
- Facial recess
- Sinus tympani
- Mastoid tip
- Protympanum
- Hypotympanum

These are areas in which the cholesteatoma can be hidden from view; therefore, the surgeon should pay particular attention to these areas and meticulously clean them.

When performing a mastoidectomy on a child under 2 years of age, the postauricular incision should not follow the postauricular crease because the facial nerve is superficial as it descends toward the stylomastoid foramen. The tympanic ring is not yet ossified. A typical postauricular incision would most surely damage the facial nerve. Thus the incision is made to swoop out, as shown in Fig. 23–2.

When performing a simple mastoidectomy in a child or in an adult such as for facial nerve decompression, the concha could collapse anteriorly postoperatively, thereby causing a hearing loss as a result of partial or complete obliteration of the
Figure 23–1 The goal of musculoplasty is to convert the cavity from (A) an hourglass shape to (B) a cylindrical shape. (From Johnson JT, Blitzer A, Ossoff RH, Thomas JR. Instructional Courses, Vol. 3. St. Louis, MO: Mosby Year Book; 1990. Reprinted with permission.)

Figure 23–2 Postauricular incision is made to swoop out inferiorly. (From Johnson JT, Blitzer A, Ossoff RH, Thomas JR. Instructional Courses, Vol. 3. St. Louis, MO: Mosby Year Book; 1990. Reprinted with permission.)
external auditory meatus. A stitch placed through the conchal cartilage with 3–0 chromic silk or Dexon®, looping around like a mattress stitch and sutured to the posterior subcutaneous tissue, will avoid this (Fig. 23–3).

◆ A patient with a natural myringostapediopexy may have very little hearing loss if the eustachian tube function is normal at the time of diagnosis. Even though the tympanic membrane looks atrophic, the patient hears well. If the patient has poor eustachian tube dysfunction and there is a lot of scar tissue, no matter how many operations are performed, the result will be poor hearing. Therefore, in the case of poor eustachian tube function, provided the patient has no infection and has a dry ear, a hearing aid is more appropriate than surgery in rehabilitating the patient’s hearing loss. Also, if the patient has fibrosis of the middle ear or has an atelectatic tympanic membrane, surgery will not be successful in improving hearing. Preoperative selection of patients is paramount in achieving good hearing results.

Landmarks for Locating the Facial Nerve

◆ The tympanic facial nerve lies anterior to the horizontal semicircular canal and posterior to the cochleariform process, immediately above the oval window. If the epitympanum is pictured as a box, its sides are the anterior wall, posterior wall,
superior wall, inferior wall, medial wall, and lateral wall. The medial wall of the epitympanum is the place where the geniculate ganglion is located, along with the horizontal portion of the facial nerve. When removing cholesteatoma from the epitympanum, the surgeon should not scrape on the medial wall and should dissect gently in this area.

◆ In the severely diseased ear after multiple operations where there are no landmarks, the promontory of the middle ear has a groove, which is where Jacobson's nerve lies. This groove always proceeds from the round window inferiorly to the cochleariform process superiorly. If all else fails, find the groove, which shows where the round window is and leads to the cochleariform process. Posterior and superior to the cochleariform process by a few millimeters is the facial nerve.

Surgical Technique

◆ The incision should be made 0.5 cm behind the postauricular crease to avoid the appearance of a plastered auricle or a depression in the crease.

◆ When the incision is carried through the full thickness of the skin, the subcutaneous and fibrous tissue is dissected to the junction of the cartilaginous and bony canal, using the Bovie coagulation cautery. Using the coagulation rather than cutting mode allows for maximum hemostasis. Remember to retract the auricle anterolaterally, applying the principle of traction and countertraction to make dissection easier.

◆ A 6 to 12 o'clock incision is then made along the posterior bony external auditory canal, 3 to 5 mm lateral to the fibrous anulus. A round knife or a lancet knife is appropriate for this step in the procedure (Fig. 23–4).

◆ The Korner flap, used in this procedure, is a posterior full-thickness skin flap based laterally at the concha. To create the Korner flap, make an incision to the helical crus (without cutting into it), staying as close to 12 o'clock as possible to obtain a broad-based pedicled flap. Because of the thicknesses of the cartilage and soft tissue, it is most effective to use a fresh sharp blade to cut gently in a seesaw motion. Too hard a push to cut through the dense tissue might end up transsecting the auricle. A similar incision is made inferiorly at the 6 o'clock position (Fig. 23–5).

◆ The seesaw technique is facilitated by holding the auricle anterolaterally. The base of the Korner flap is flared and released by cutting the superior and inferior attachments to the concha with a pair of curved Stevens scissors (Fig. 23–5).

◆ Excess adipose-connective tissue should be trimmed off with a no. 11 blade. Countertraction can be provided with a mosquito snap, but the surgeon should exercise caution not to “buttonhole” the flap.

◆ Using a no. 15 blade, remove a generous crescent piece of the conchal cartilage while pushing the index finger posteriorly in the external auditory meatus. This gives rise to a wide meatoplasty. Again, be careful not to buttonhole the pedicle.

◆ The inferiorly based muscle flap is made with the coagulation mode of the electrocautery. If it is known that no cholesteatoma remains, the inferiorly based muscle flap is placed in the mastoid cavity to obliterate the cavity partially.
Figure 23–4 A round or lancet knife is used to make a 6 to 12 o’clock incision along the posterior bony canal. (From Johnson JT, Blitzer A, Ossoff RH, Thomas JR. Instructional Courses, Vol. 3. St. Louis, MO: Mosby Year Book; 1990. Reprinted with permission.)

Figure 23–5 A Korner flap is released by cutting superior and inferior attachments to the concha with a pair of curved Stevens scissors. (From Johnson JT, Blitzer A, Ossoff RH, Thomas JR. Instructional Courses, Vol. 3. St. Louis, MO: Mosby Year Book; 1990. Reprinted with permission.)
Note that it is the author’s technique to usually obliterate only the inferior aspect of the cavity. Cholesteatoma must be completely removed, and, in most cases, any squamous epithelium left unknowingly is located in the upper portion of the cavity, such as near the sinodural angle and mastoid tegmen. Because the inferior aspect of the cavity is also the area predisposed to postoperative debris accumulation, which can lead to infection, the cavity size should be reduced with an inferiorly based pedicle flap. This is not to be confused with “blindly” obliterating the whole cavity, thus introducing the strong possibility of burying cholesteatomatous disease. Again, the goal of this procedure is to make the shape of the cavity and the ear canal more cylindrical than hourglass, thereby minimizing the cavity.

The temporalis fascia is placed in a fascia press, spread thin, and given just one click (too many clicks may destroy the graft). When this is dried, it looks like a tympanic membrane.

Another technique for reconstructing the perforated tympanic membrane as well as lining the cavity with temporalis fascia is to create a large temporalis fascial flap based anterosuperiorly, with its own blood supply. It goes without saying that the temporalis fascia should not cover squamous debris or cholesteatoma. This technique has served well in patients with persistent disease after multiple revision surgeries. The negative aspect is that the skin incision must be extended superiorly from the typical postauricular incision. For those surgeons who are familiar with the endaural approach, the incision can be an extension of the endaural incision.

Pitfalls

In mastoidectomy, the common mistake among residents is to attempt to locate the antrum too posteriorly or too inferiorly, thereby looking for a hole that is not there, risking injury to the horizontal canal, facial nerve, sigmoid sinus or temporal lobe dura (Fig. 23–6). The spine of Henle is a good surface marker for the approximate medial-lateral location of the antrum.

Management of Intraoperative Complications

If the dura is exposed when drilling during mastoidectomy and a cerebrospinal fluid (CSF) leak does not result, this is not cause for alarm. The patient should be placed (1) on one bolus of antibiotic and (2) on antibiotics orally postoperatively for 1 week. If, however, the patient has a CSF leak, then the patient should remain in the hospital for at least 24 to 48 hours on intravenous antibiotics. The CSF leak should be repaired with fascia and muscle grafts in an underlay fashion prior to closing the wound.

If a fistula is made in the semicircular canal, make sure there are no ototoxic drugs such as Cortisporin® in the operative field. Furthermore, suction should not be applied on the fistula. Instead, saline-soaked Gelfoam should be placed over the fistula while the operation is carefully completed. At the end of the procedure, a fascia graft is used to cover the fistula.
◆ If the sigmoid sinus is lacerated during surgery, it should be tightly packed with Surgicel to control bleeding.
◆ The patient’s facial nerve status should be established as soon as the patient is awake in the recovery room. If an immediate complete facial nerve palsy is noted, reexploration within 12 to 24 hours is required. If a delayed or incomplete facial palsy is noted, it can be treated with steroids, loosening the mastoid/canal packing, and eye care as necessary.

Figure 23–6 Simple mastoidectomy cavity showing horizontal canal and short process of incus. (From Johnson JT, Blitzer A, Ossoff RH, Thomas JR. Instructional Courses, Vol. 3. St. Louis, MO: Mosby Year Book; 1990. Reprinted with permission.)
Myringotomy with Tube Placement

K. J. Lee

◆ Surgical Technique

◆ Myringotomy and pressure-equalizing (PE) tube insertion is mostly easily performed under general anesthesia in infants and children, whereas local anesthesia is effective for most adults. If local anesthesia is used, two options are available for use:

◊ *Ear canal injection* 1 cc of 1% lidocaine (Xylocaine) with epinephrine 1:100,000 is injected into the canal wall skin at four to six equal positions at the chondro-osseous junction. This is best accomplished with an angled 25-, 27-, or 30-gauge, 1.5 inch needle to provide optimal visibility while injecting. The bevel of the needle should abut the canal wall bone (under the periosteum). To reduce pain, infiltration should begin in previously anesthetized regions after the first injection. Injection should be done slowly so that the solution does not enter the middle ear. Do not inject the tympanomeatal flap. Anesthetic in the middle ear can produce 25 minute delayed vertigo if the solution crosses the round window membrane or temporary facial paralysis in a patient with a dehiscent facial nerve.

◊ *Topical phenol* Gives adequate anesthesia for myringotomy and does not give any postoperative complications.

◆ With the use of no. 5 or 7 Baron suction, a wax loop, and an alligator forceps for adherent fragments, the external canal is cleared of all debris and cerumen. Abrasion of the thin anterior canal wall skin should be avoided, because bleeding will obstruct the view of the tympanic membrane.

◆ An oval, beveled speculum of largest possible diameter is inserted into the external canal with the bevel anteriorly. This snug speculum fit will provide optimal visualization, as well as reduce canal wall trauma. The anterior canal wall bony
bulge, a frequent trouble spot, can be easily negotiated by tilting the speculum posteriorly when the bulge is encountered, advancing toward the tympanic membrane, then tilting anteriorly.

- The tympanic membrane is inspected, and landmarks are identified. Visualization of the umbo provides orientation, particularly when a thickened or bulging membrane obscures normal landmarks. This is especially important in young children under mask anesthesia when fear of airway obstruction prompts the surgeon to move quickly. The tympanic membrane should be examined for perforation, retraction, myringosclerosis, or monomer formation to ensure PE tube placement is in a healthy portion of the drum.

- The type of PE tube used and its position on the tympanic membrane determines the duration of middle ear ventilation. Epithelial migration of the squamous portion of the drum, thought to be responsible for tube extrusion, radiates from the umbo. This migration is fastest in the posteroinferior and anteroinferior quadrants, followed by the posterosuperior and anterosuperior quadrants, respectively. The anterosuperior quadrant is thus the optimal location for prolonged tube position. Tube insertion in the posterosuperior quadrant obviously is contraindicated because of location of the ossicles. The inferior quadrants may be used for shorter periods of middle ear ventilation and are the most accessible.

- A straight or angled myringotomy knife is inserted into the tympanic membrane, and the myringotomy incision is lengthened by a slight sawing motion of the knife. The direction of the myringotomy incision is important. A radially oriented incision parallels the direction of epithelial migration, whereas the circumferential incision is perpendicular to it. Epithelial accumulation is thus greater with a circumferential incision, producing a faster extrusion rate. Bleeding from the tympanic membrane is usually minimal, but if troublesome, it may be controlled with cotton pledgets saturated with epinephrine solution (1:1000). Profuse bleeding at myringotomy may be due to an aberrantly located jugular bulb. Packing the middle ear with Gelfoam® and the external canal with Nu-Gauze® will tamponade the hemorrhage.

- After myringotomy, any fluid in the middle ear is suctioned with a no. 3 or 5 Baron suction. If secretions are thick and tenacious, saline irrigation with a no. 7 Baron suction is helpful. The outer flange of the PE tube, opposite the leading edge, is now grasped with an alligator forceps and introduced into the external canal without touching the canal wall. In a small canal the tube should be grasped by the inner flange. A PE tube inserter may also be used.

- The leading edge of the inner flange is then engaged in the myringotomy incision (Fig. 24–1). It is important to make sure that the anterior edge of the inner flange is within the incision. With the use of the myringotomy knife or the tip of a Rosen needle, firm pressure is applied to the junction of the shaft and the inner flange in an anteromedial direction to “pop” the posterior portion of the inner flange under the posterior edge of the myringotomy site, thus inserting the tube. This method works best for firm polyethylene tubes. Soft PE tubes such as silicone are more difficult to insert and require a slightly larger myringotomy incision. Occasionally a PE tube is lost in the middle ear on insertion. Careful retrieval should be attempted through the myringotomy, with attention to the risk of ossicular disruption. If necessary, a tympanomeatal flap should be raised to retrieve a tube lodged in
After placement of the tube, patency is ensured by clearing the tubal orifice of any blood or mucus by suctioning with the thumb off the suction vent. This prevents suctioning the tube out of the myringotomy incision. Sterile saline can be used to irrigate the orifice until clear. Epinephrine-saturated cotton pledgets will control persistent bleeding around the tube. If tubal patency remains in question as a result of continuous drainage from the middle ear, non-ototoxic otic drops are administered in the immediate postoperative period.
Surgical treatment of vertigo is characteristically directed at peripheral vestibular disorders. The role of surgery is directly dependent on the nature of the pathology. Surgical treatment of these disorders can be directed at the specific part of the inner ear causing the dysfunction or at ablating inner ear function or dividing the afferent connections to the central nervous system. Chemical ablation of vestibular function is discussed in Chapter 26.

◆ **General Principles**

◆ As with most otologic problems, surgery should be considered only when medical management has failed to control the patient’s vestibular symptoms adequately.

◆ The choice of surgical intervention is predicated on the status of hearing in the involved and contralateral ear, vestibular function in the contralateral ear, physiologic age of the patient, and medical health of the patient.

◆ Nonablative options should be considered in bilateral disease to avoid the problem of oscillopsia.

◆ Patients with nonlocalizing pathology or an uncategorized vestibulopathy should not be considered candidates for surgical intervention.

◆ Preoperative vestibular testing is used to confirm the ear affected.

◆ **Benign Paroxysmal Positional Vertigo**

**Posterior Semicircular Canal Occlusion**

◆ This procedure is indicated for disabling positional vertigo resulting from canalithiasis involving the posterior semicircular canal despite multiple attempts at particle repositioning maneuvers.
The procedure is performed under general anesthesia, with standard prep and drape for postauricular surgery.

Intraoperative facial nerve monitoring is not routinely used.

Perioperative antibiotics are administered in patients with prior otitis media.

Through a standard postauricular incision, a limited mastoidectomy is performed for exposure of the mastoid antrum and lateral semicircular canal. The spine of Henle laterally guides the surgeon to the approximate location of the lateral semicircular canal. In the case of a sclerotic mastoid, always stay close to the posterior bony external auditory canal, and proceed anterosuperiorly along the mastoid tegmen to avoid injury to an anteriorly placed sigmoid sinus.

The posterior semicircular canal is located posterior to and at a 90 degree angle to the lateral canal. The superior semicircular canal is located at a deeper plane relative to these two canals and is generally not encountered during this procedure. Air cells surrounding the posterior semicircular canal are removed using a 3 or 4 mm diamond bur.

The area to be exposed for occlusion is below the level of the lateral semicircular canal. A small diamond drill bur is used to thin the bone of the bony otic capsule encasing the membranous portion of the vestibular labyrinth to eggshell thickness over a 180 degree circumference, creating a 1 × 3 mm bony fenestrum.

The remaining eggshell of bone is then carefully removed using a sharp 90 degree pick.

Avoid suctioning over the membranous labyrinth to minimize the risk of sensorineural hearing loss. Any perilymph or irrigation fluid should be wicked away using a small cottonoid.

The lumen of the posterior semicircular canal is then occluded with a plug of bone wax or bone pate collected at the time of mastoidectomy. This effectively occludes the membranous endolymphatic space, precluding the possibility of otoconia drifting within this compartment. The advantage of using bone pate is subsequent ossification of the canal, ensuring permanent canal occlusion.

The fenestrum, along with the plug, is then covered with a piece of temporalis muscle or fascia, held in place with Surgicel® or Tisseal® (human fibrinogen glue).

The postauricular incision is closed in two layers, and a mastoid dressing is applied over the ear for 24 hours.

Postoperative dizziness, disequilibrium, or motion sensitivity may necessitate hospitalization until the patient is able to ambulate. Early vestibular rehabilitation is indicated in patients with residual vestibular symptoms.

Posterior Ampullary Nerve Section/Singular Neurectomy

This procedure has largely been replaced by posterior semicircular canal occlusion, which carries a lower risk of sensorineural hearing loss.

The procedure is generally performed under local anesthesia through a transcanal approach. Perioperative antibiotics are not generally used.

The canal is injected with 1% lidocaine with 1:100,000 epinephrine solution.

A tympanomeatal flap is elevated to expose the middle ear and identify the round window. Any bony overhang over the round window niche is carefully
removed using a small diamond drill bur to fully expose the round window membrane.
◆ The bone just inferior to the round window membrane is drilled ~2 mm deep until the singular canal is encountered and the posterior ampullary nerve fibers identified. The nerve fibers are destroyed using a small sharp hook. One should be cognizant of the proximity of this canal to the ampulla of the posterior semicircular canal to avoid probing too deeply within the canal.
◆ The resultant bony depression is then obliterated using bone dust or bone wax. Should cerebrospinal fluid (CSF) leakage from the singular canal be encountered (rare), a small piece of fat or similar soft tissue may be used to control further leakage.
◆ The tympanomeatal flap is then returned to its normal position, and the external auditory canal packed with Gelfoam®, which may be removed after 1 to 2 weeks, or allowed to dissolve and disintegrate using commercially available otic preparations.
◆ Postoperative dizziness and disequilibrium may necessitate hospitalization until the patient is ambulatory.

◆ **Endolymphatic Hydrops/Meniere’s Disease**

There are three surgical procedures used for control of vertigo in Meniere’s disease if medical therapy has failed. They are endolymphatic sac procedures, vestibular nerve section, and labyrinthectomy.

◆ Labyrinthectomy is reserved for patients with no useful hearing in the affected ear.
◆ Caution should be exercised in offering vestibular nerve section and labyrinthectomy for patients with bilateral disease.

**Endolymphatic Sac Decompression/Shunt Surgery**

◆ These procedures offer lower success rates for vertigo control compared to vestibular nerve section, but with less risk of hearing loss in patients with aidable residual hearing.
◆ Surgery is performed under general anesthesia with standard prep and drape for mastoid surgery. Facial nerve monitoring is optional, and not used routinely for this procedure.
◆ The postauricular incision is made slightly posterior to the standard mastoid access incision so that the same incision may be used for vestibular nerve section in the event of persistent vertigo.
◆ A simple mastoidectomy is performed to access the mastoid antrum and to identify the lateral semicircular canal. The sigmoid sinus marks the posterior limit of mastoid exposure.
◆ The posterior fossa plate is skeletonized between the level of the lateral semicircular canal (Donaldson’s line) superiorly and the jugular bulb inferiorly, and between the posterior semicircular canal anteriorly and the sigmoid sinus
posteriorly. The sigmoid sinus may be decompressed and retracted posteriorly for added exposure in contracted mastoids. The endolymphatic sac is found medial to the retrofacial air cells and inferior to the posterior semicircular canal.

- The endolymphatic sac is identified as a thickening in the posterior fossa dura through the overlying bone and is widely decompressed. This would be the extent of exposure if sac decompression is the end point of surgery.
- For endolymphatic shunt surgery, the lateral wall of the sac is incised. The lumen of the sac is identified using an anulus elevator or similar blunt instrument. Care is taken not to violate the medial wall of the sac and enter the subarachnoid space. If the medial wall of the sac is inadvertently violated and CSF encountered, small defects may be plugged with temporalis muscle/fascia and sealed in place using Tisseal. The use of postoperative antibiotics should also be considered if this occurs.
- A variety of “shunts” may be inserted between the walls of the endolymphatic sac for sustained decompression, such as thin Silastic sheeting, Teflon sheeting, tubes, and valves.
- After complete hemostasis, the postauricular wound is closed in two layers, and a mastoid dressing is applied for 24 hours.
- The patient may usually be discharged home on the day of surgery.

Vestibular Nerve Section

- Indicated for patients with disabling vertigo and aidable hearing. These are patients who have generally failed medical therapy and endolymphatic shunt surgery, although nerve section may be performed as a primary procedure in some cases. Several surgical approaches through the posterior and middle fossa may be used for this procedure.

Retrolabyrinthine Approach

- Most popular approach used by neurotologists for vestibular nerve section; may be performed without neurosurgical support
- Advantage: lower incidence of headache after surgery
- Surgical technique
  - Patient is positioned and prepared, as for standard mastoid surgery.
  - Intraoperative facial nerve and brainstem auditory evoked potentials are monitored.
  - Perioperative antibiotics are administered at induction of general anesthesia, and for 24 hours after surgery, along with intravenous dexamethasone.
  - After injection with 1% lidocaine with 1:100,000 epinephrine, a postauricular C-shaped incision is made 3 cm behind the postauricular crease, and postauricular soft tissues are elevated in the usual fashion to create a musculoperiosteal flap for layered wound closure.
  - A complete mastoidectomy is performed, and the lateral and posterior semicircular canals are identified and skeletonized.
The sigmoid sinus and bone behind it are decompressed, followed by decompression of the middle and posterior fossa dura up to the posterior semicircular canal.

A large anteriorly based U-shaped incision is then made in the presigmoid dura and tacked anteriorly. The endolymphatic sac and duct are usually preserved, although some surgeons advocate a concomitant shunting of the endolymphatic sac at this time.

A neurosurgical cottonoid is advanced between the surface of the cerebellum and under the anterior edge of the dura, until the arachnoid surrounding the cerebellopontine cistern is encountered. The arachnoid is opened to drain cerebellopontine cistern CSF. This allows the cerebellum to fall away, exposing contents of the posterior fossa.

Cranial nerves V, VII, VIII, IX, X, and XI are identified. CN VIII is then examined under higher magnification, and the course of the adjacent CN VII is confirmed with electrical stimulation. The vestibular nerve is usually grayish and lies superiorly near the brainstem, whereas the cochlear nerve is whitish. A small vessel is usually identified running between the nerves. Electrical stimulation of the facial nerve is performed before, during, and after vestibular nerve section.

A Roton no. 1 dissector is used to separate the cochlear and vestibular nerves close to the brainstem. Curved microscissors are then used to cut the vestibular nerve from a superior to inferior direction. Complete vestibular nerve section is performed to the level of the nervus intermedius, which is whiter and lies between the cochlear and vestibular nerve. Usually a 5 to 10 mm segment of vestibular nerve is excised to complete the vestibular nerve section.

Once hemostasis is secured, the dural flap is reapproximated using 4–0 Nurolon sutures, and the mastoid defect is packed with strips of fat harvested at the time of surgery, from the left lower quadrant of the abdomen.

The postauricular wound is then closed in layers, and a mastoid dressing is applied for 72 hours.

Hospital stay after surgery for 5 to 10 days may be required. Vestibular suppression is offered in the immediate postoperative period, to control symptoms of severe vertigo. Vestibular rehabilitation should be instituted early to accelerate central vestibular compensation.

Results

Control of vertigo: over 90% in Meniere’s disease, but postoperative disequilibrium is variable and may occasionally be disabling. Hearing is preserved at preoperative levels is 75 to 85% of patients. Delayed hearing loss may occur up to 2 years after surgery. Risk of total hearing loss is 2%. Facial nerve palsy (< 1%), CSF leak, and meningitis are other potential postoperative complications.

Retromastoid/Retrosigmoid Approach

Commonly used by neurosurgeons

Advantages: provides most consistent and direct exposure of the cochleovestibular and facial nerves between the porus of the internal auditory canal (IAC) and the
brainstem within the cerebellopontine angle; reduced risk of injury to the facial nerve, which lies anterior to the cochleovestibular nerve complex from this approach

- Disadvantage: in this area, the vestibular portion of the vestibulocochlear nerve is not anatomically separate from the cochlear nerve. There is the risk of leaving some vestibular fibers uncut.

- Surgical technique
  - Patient is placed supine with head in a Mayfield head holder and pins, head turned away from the surgeon. A soft roll is placed under the ipsilateral shoulder.
  - Preparation, intraoperative neurophysiologic monitoring and draping are similar to the retrolabyrinthine approach.
  - The skin incision is an oblique linear one beginning 3 to 4 cm behind the mastoid tip and extending anterosuperiorly for 5 cm.
  - The mastoid emissary vein is usually encountered, isolated, and divided. The bony foramen of the vein is occluded with bone wax.
  - A retrosigmoid craniotomy is performed behind the sigmoid sinus and below the transverse sinus. Any visualized mastoid air cells are occluded with bone wax.
  - The dura is then incised, and flaps are created to expose the posterior cranial fossa.
  - Exposure of the posterior fossa and vestibular nerve section are accomplished in a similar fashion to the retrolabyrinthine approach.
  - After nerve section is complete and hemostasis secured, the dura is reapproximated, a small amount of adipose tissue is packed gently into the craniotomy site, and the bone flap is secured back in place. Layered wound closure is then accomplished, and a light dressing is applied.

- Results
  - As for retrolabyrinthine vestibular nerve section

**Middle Fossa Approach**

- Used as a secondary procedure after failed posterior fossa vestibular nerve section in patients with useful hearing
- Advantage: vestibular nerves are sectioned laterally in the IAC where they have clearly separated from the cochlear nerve, thus increasing the likelihood of complete nerve section. Dissection is mostly extradural.
- Disadvantage: increased risk of facial nerve paralysis (usually temporary) and sensorineural hearing loss; technically more difficult due to variable middle fossa floor anatomy
- Surgical technique
  - Details of a basic middle fossa approach are described in Chapter 28 for middle fossa decompression of the facial nerve.
  - Once the middle fossa floor is exposed, the retractor placed, and landmarks identified, skeletonization of the IAC is initiated medially along the petrous ridge and continued laterally. Because of the proximity of the cochlea
anteriorly and the ampulla of the superior semicircular canal posteriorly, only a 90 degree circumference of the IAC is unroofed laterally until Bill’s bar is identified.

- Once the dura of the IAC is identified and exposed, it is incised along the posterior half and raised as anterior and posterior flaps to expose the contents of the IAC. The facial nerve is identified anterosuperiorly within the IAC and confirmed using electrical stimulation.

- The vestibulofacial anastomotic fibers in the lateral IAC are divided. Both superior and inferior vestibular nerves are sectioned, as is the singular nerve. A segment of the nerves containing Scarpa’s ganglion is excised to ensure complete nerve section.

- Care is taken not to disrupt any blood vessels within the distal IAC so as not to compromise cochlear function.

- The dural flaps are then replaced, the bony defect is gently packed with small strips of abdominal fat graft, and the middle fossa retractor is removed to release the temporal lobe over this area. The craniotomy flap is replaced. Plate and screw fixation of the bone flap is optional.

- Wound closure is accomplished in layers, and a mastoid dressing is left in place for 72 hours.

**Results**

- The risk of total hearing loss (5%) and transient facial paresis/paralysis (3–7%) are slightly higher compared to that incurred using the retrolabyrinthine and retrosigmoid approaches. Complete nerve section is more likely with this technique.

**Translabyrinthine Approach**

- Indicated for patients with disabling vertigo and no useful hearing in the affected ear. This offers a preganglionic vestibular nerve section, in addition to complete removal of all neuroepithelium.

- Surgical technique

  - The general approach and procedure are as described for translabyrinthine acoustic neuroma resection in Chapter 30.
  - A complete labyrinthectomy is integral to the procedure.
  - The IAC is dissected only in the lateral half. Both Bill’s bar (vertical crest) and transverse crest are identified laterally in the bony IAC.
  - A hook is placed behind Bill’s bar to avulse the superior vestibular nerve. The dura over the posterior IAC is then opened. Vestibulofacial anastomoses in the lateral IAC are divided, and both superior and inferior vestibular nerves are divided medial to Scarpa’s ganglion.

- Wound closure is as described in Chapter 30.

**Labyrinthectomy**

- Indicated for persistent vertigo or uncompensated peripheral vestibulopathy in a nonhearing ear. This may be performed chemically (see Chapter 26) or surgically. This section describes the surgical labyrinthectomy procedure.
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◆ Surgical technique

◇ Performed under general anesthesia through a standard transmastoid incision and approach. Preparation and draping are therefore similar to that used for standard mastoid surgery.
◇ Intraoperative facial nerve monitoring is employed.
◇ Perioperative antibiotics are administered at induction of anesthesia.
◇ A complete mastoidectomy is performed, with identification and skeletonization of the lateral and posterior semicircular canals initially, followed by the superior semicircular canal on a deeper plane. All perilabyrinthine air cells are removed.
◇ The vertical facial nerve should be identified and skeletonized.
◇ The tegmen mastoideum is thinned with a medium diamond bur.
◇ The labyrinthectomy is performed by systematically opening each of the three semicircular canals and their corresponding ampullae, and vestibule, to access and remove all five groups of neurosensory epithelium. The superior wall of the lateral semicircular canal is first fenestrated in an anterior to posterior direction, followed by the lateral wall of the posterior semicircular canal in an inferior to superior direction. This will lead the surgeon to the common crus and superior semicircular canal. Bone is left over the inferior wall of the lateral canal, which protects the second genu of the facial nerve; the inferior wall of the posterior semicircular canal, which protects a high-riding jugular bulb; and the medial wall of the superior semicircular canal ampullae, which protects the facial nerve anterior to the superior vestibular nerve at the fundus of the IAC. Medium cutting burs are used on the bony labyrinth because the bone is very hard. Continuous suction-irrigation is used to remove bone dust as drilling is continued.
◇ All semicircular canal ampullae must be exposed and opened. The ampulla of the posterior semicircular canal lies medial to the facial nerve and must be carefully exposed.
◇ The neuroepithelia of the three semicircular canal ampullae, the utricle, and the saccule are completely removed.
◇ If no CSF leak is noted, the wound may be closed in a layered fashion as for routine mastoid surgery. If a leak is detected, the incus is removed to obliterate the eustachian tube and middle ear with temporalis fascia and muscle, and the mastoid cavity is packed with an abdominal fat graft.

◆ Perilymphatic Fistula

◆ This remains a controversial diagnosis except in cases of obvious physical trauma or barotrauma to the ear. In children, the diagnosis is entertained if progressive, sudden, or fluctuating hearing loss is encountered.
◆ There is no reliable diagnostic test. Definitive diagnosis is made at the time of surgical exploration. Audiometric testing is performed to assess preoperative hearing levels in the affected ear.
◆ Most suspected fistulae may be managed conservatively. If symptoms persist despite conservative management with avoidance of strenuous activity, and possibly bed rest, surgical exploration is offered.
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◆ Surgical technique

○ Surgery is performed under general anesthesia in children, and local anesthesia with sedation in adults. The awake patient may provide the surgeon with immediate feedback regarding vestibular symptoms.

○ Standard preparation and draping for transcanal surgery. If a vein graft is to be used, the dorsum of the contralateral hand is prepared as well.

○ The canal is anesthetized with 1% lidocaine with 1:100,000 epinephrine solution.

○ A tympanomeatal flap is elevated to enter the middle ear.

○ The posterosuperior canal wall may have to be curetted to visualize the oval window fully.

○ Both round and oval windows are inspected. The diagnosis of perilymph leak is based on seeing clear fluid reaccumulating around the windows. Diagnosis may be further enhanced by asking anesthesia to apply positive pressure on ventilation.

○ If a leak is confirmed at this time, a soft tissue graft is harvested from the temporalis fascia, dorsal hand vein, or tragal perichondrium. Adipose tissue is not used because of its tendency to atrophy over time.

○ The integrity of the ossicular chain is examined. In traumatic leaks, the stapes is violated in some manner. If the footplate is subluxed into the vestibule, it may be carefully elevated using angled picks. If the patient complains of excessive nausea or vertigo, stapes manipulation is discontinued. If the stapes is significantly disrupted, a partial or total stapedectomy technique is used to reconstruct ossicular continuity.

○ In leaks occurring after stapedectomy surgery, the prosthesis usually must be removed, and a fresh soft tissue graft is laid over the oval window. The stapes prosthesis is then replaced to secure the tissue graft in place.

○ The mucosa is elevated from the margins of the oval or round window. The oval or round window niche is packed with small pieces of fibrofascial tissue, between and around the crura of the stapes. The soft tissue seal is secured in place using Gelfoam, Avitene, Surgicel, or fibrin glue.

○ The tympanomeatal flap is then replaced, and the ear canal is packed with ointment or antibiotic-soaked Gelfoam.

○ The patient may be discharged home on the day of surgery if no significant postoperative vestibular symptoms are experienced. Dry ear precautions are observed for 3 weeks, at which time any residual ear canal packing is removed and a postoperative audiogram obtained.

◆ Superior Semicircular Canal Dehiscence Syndrome

◆ This syndrome causes sound- and/or pressure-induced vertigo and is due to a bony dehiscence of the superior semicircular canal.

◆ Diagnosis is made on high-resolution computed tomography (CT) imaging of the temporal bone in the parasagittal plane of the superior semicircular canal.
Surgical repair of the superior semicircular canal dehiscence is offered only if symptoms are disabling and diagnosis is confirmed on CT imaging.

**Surgical technique**

- A middle fossa craniotomy is used to access the superior semicircular canal.
- A smaller temporal craniotomy may be performed because less medial access is required for this procedure compared with IAC surgery.
- Dural elevation over the middle fossa floor is performed carefully so as to avoid tearing the membranous labyrinth of the dehiscent canal.
- Several techniques are used to repair the bony defect:
  - Plug the superior semicircular canal with bone wax or bone pate (compacted bone dust).
  - Resurface the middle fossa floor with fascia, homograft dura, or pericardium.
  - Combination of both techniques.

**Uncompensated Peripheral Vestibulopathy**

- Pathology must be localized to the peripheral vestibular system on vestibular testing.
- Vestibular rehabilitation therapy should be maximized. Surgery is offered only to patients with persistent disabling disequilibrium. The goal of surgical treatment is to completely deafferentize the peripheral vestibular system.
- Treatment options are dependent on hearing status of the affected ear:
  - Hearing ear: vestibular nerve section (retrolabyrinthine, retrosigmoid, or middle fossa)
  - Nonhearing ear: labyrinthectomy.
Inner ear perfusion refers to the administration of drugs through the tympanic membrane into the middle ear for absorption into the inner ear through the round window membrane. It has become increasingly popular as a treatment modality for a variety of inner ear disorders, offering the theoretical advantages of:

- Direct delivery of medication to the diseased ear, thus avoiding effects on the contralateral ear and potential side effects of systemic therapy
- Higher perilymph concentration of the medication
- Minimally invasive, office-based administration of treatment

The most commonly used drugs for this form of treatment include aminoglycosides and steroids. Intratympanic injection of other drugs for a variety of inner ear disorders remains controversial and is therefore not discussed in this chapter.

**Intratympanic Aminoglycosides**

- **Indication for treatment** Control of recurrent episodic vertigo in unilateral Meniere's disease despite maximal medical therapy
- **Treatment principle** Partial or complete chemical vestibular ablation. The ability to titrate treatment based on clinical symptoms is a distinct advantage of this treatment relative to surgical vestibular ablation. The disadvantages include difficulty in predicting duration of treatment, potentially higher risk of sensorineural hearing loss, and variable outcomes. The variable course of Meniere's disease complicates direct comparison of surgical and chemical vestibular ablation outcomes.
- **Drugs used** Most commonly used drugs include gentamicin and streptomycin, both of which are preferentially vestibulotoxic. The availability of streptomycin...
in the United States at this time is restricted. Gentamicin is currently the preferred drug.

- **Dosage**  Gentamicin 30 mg/mL is compounded on the day of treatment; 1.5 mL of commercially available gentamicin for injection (40 mg/mL) is buffered with 0.5 mL of 0.6 M sodium bicarbonate, to reduce pain on injection.

- **Treatment protocol**  This varies by surgeon but is most commonly administered as a single injection and titrated by symptoms thereafter, or as a predetermined number of injections at weekly intervals. Prolonging the interval between injections and minimizing the total number of injections reduce the risk of hearing loss.

- **Treatment end point**  Disequilibrium is usually experienced 2 to 3 days after the injection and may continue for a variable period after treatment. The goal of treatment is elimination of vertigo attacks. This may be achieved at the expense of long-term disequilibrium. Complete vestibular ablation (measured by absent caloric responses in the injected ear) is no longer the end point of therapy. Treatment should be titrated to the patient’s clinical symptoms and discontinued when no further vertigo attacks are experienced or hearing deterioration is noted.

- **Complications**  The most common complication is hearing loss. Others include tympanic membrane perforation, infection, drug sensitivity, and bleeding.

- **Results**  Vertigo control in up to 90%. Risk of hearing loss in up to 30%.

◆ **Intratympanic Steroids**

- **Indications for treatment:**
  - **Sudden sensorineural hearing loss**  Oral steroids are considered the current standard of care for this condition. The precise role of intratympanic steroids in this setting is not clear. Intratympanic steroids may be offered when (1) medical comorbidity contraindicates the use of systemic steroids, (2) oral steroids fail to improve hearing, (3) hearing loss is severe, and (4) combination therapy is considered theoretically advantageous to maximize the dose of steroids reaching the inner ear.
  - **Meniere’s disease**  Used to provide short-term control of vertigo in ears with good hearing. Compared with intratympanic aminoglycoside therapy, the risk of hearing loss is lower, but effects are generally not as prolonged. For the latter reason, steroids are less commonly used than aminoglycosides for intratympanic treatment of Meniere’s disease.

- **Drugs and dosages used**  Dexamethasone (4, 10, or 24 mg/mL), methylprednisolone (40 mg/mL).

- **Treatment protocol**  No universal protocol has been established for either indication. For sudden sensorineural hearing loss, treatment may be administered as a single injection with audiometric follow-up in 7 to 14 days and additional injections offered if partial recovery is demonstrated, or as a series of injections over 1 to 2 weeks followed by audiometric testing at the end of the injection series. Similar protocols may be used in Meniere’s disease, with vertigo control or hearing improvement being the goals of treatment.
Treatment end point  Steroid therapy is thought to be effective within the initial 2 to 4 weeks following onset of sudden sensorineural hearing loss. As such, further injections beyond this time frame are unlikely to be beneficial. In Meniere’s disease, treatment may be offered as necessary for symptomatic periods if medical therapy is ineffective.

Complications  Similar to intratympanic aminoglycoside therapy, although the risk of additional hearing loss is low.

Results  The outcomes for intratympanic steroid therapy in sudden hearing loss are variable. Clinical trials are currently in progress to better define the role of this treatment modality in sudden sensorineural hearing loss. Vertigo control in Meniere’s disease using intratympanic steroids is not as sustained relative to intratympanic aminoglycoside therapy, although the risk of hearing loss is significantly lower and the potential for hearing improvement exists.

Perfusion Technique

The simplest and most commonly used technique for intratympanic therapy is by injection through an intact tympanic membrane. Alternative techniques include injection or self-administration of otic solutions through a myringotomy tube, use of infusion catheters (IntraEar Catheters, DURECT Corporation, Cupertino, CA), and the Silverstein MicroWick (Micromedics, Inc., St. Paul, MN) technique. These latter techniques may be more appropriate if repeated treatments are anticipated. The author prefers the injection method, which is described below.

The patient is placed supine or reclined in an examination chair with the head turned away from the surgeon.

A surgical microscope is used to visualize the tympanic membrane.

The tympanic membrane is anesthetized using topical 10% phenol in two focal spots in the anterosuperior and posteroinferior quadrants. Any excess phenol is suctioned away.

0.4 to 0.5 cc of the injection solution, warmed to room temperature, is drawn up into a tuberculin or 1 cc syringe loaded with a 1.5 inch, 25-gauge needle. The needle may need to be slightly bent at the hub to maintain a binocular view of the tympanic membrane at the time of injection.

An anterosuperior puncture is made using the 25-gauge needle loaded on the syringe to provide an escape port for displaced middle ear gases. The injection solution is then slowly injected through a posterosuperior quadrant puncture. This usually causes some discomfort and, on occasion, transient vertigo from caloric stimulation of the inner ear. The patient should be forewarned of this. In most cases, injection of a total of 0.4 cc of solution is possible, after which egress through the anterosuperior ventilation port will occur.

If injections are performed through a myringotomy tube, a separate ventilation port is still made. In fact, due to gross size discrepancies between the lumen of the tube and the ventilation port, it is not uncommon for retrograde egress of injection fluid to occur through the tube at the time of injection. For this reason, the injection
may alternatively be administered through a separate puncture site, using the myringotomy tube as a ventilation port instead.

- The patient is asked to remain in this supine position with the head turned for 15 to 30 minutes after the injection. Swallowing of saliva is avoided during this time period. These measures theoretically minimize drainage of the injection solution through the eustachian tube into the pharynx and maximize duration during which the solution may be absorbed through the round window membrane. Sterile cotton is placed in the external auditory meatus to soak up any excess solution.

- Because mild persistent dizziness is possible but uncommon immediately after the injection, the patient is always instructed to come accompanied by a potential designated driver.

- Dry ear precautions are maintained for 2 weeks after the procedure. This is the approximate healing time for these clean tympanic membrane puncture sites.

- If treatment is being administered for sudden hearing loss, a follow-up audiogram is obtained in 1 week. Even with Meniere's disease, a post-procedure audiogram should be obtained to document hearing in the treated ear.

**Pearls**

- The injection solution must be warmed to at least room temperature prior to injection to minimize caloric stimulation of the inner ear.

- Some surgeons "top up" the injected solution at 10 minute intervals after injection to maximize drug absorption through the round window membrane.

- Methylprednisolone is generally a less painful injection compared to dexamethasone. Some surgeons mix 1% Xylocaine (lidocaine) solution with methylprednisolone to reduce discomfort at the time of injection.

- Steroid concentrations may be increased with subsequent injections if the initial injection is ineffective.

- Myringotomy tubes placed explicitly for the purpose of inner ear perfusion should be inserted in the posteroinferior quadrant and may be removed after therapy has been completed.
This chapter discusses the surgical technique for placement of cochlear and bone-anchored hearing implants. Although middle ear implants are currently available for rehabilitation of mild to severe sensorineural hearing loss, the superiority of existing conventional hearing aid technology has resulted in limited interest in these implants as a reliable option for hearing rehabilitation.

◆ **Bone-Anchored Hearing Aids/Implants**

**Components of Device**

- External sound processor: digital ear-level (Divino) and body-level (Cordelle) devices are available (Baha System, Cochlear Americas, Denver, CO)
- Titanium fixture (Baha System, Cochlear Americas, Denver, CO)

**Indications for Implantation**

- Conductive or mixed hearing loss in patients unable to use conventional aids due to atretic or extremely stenotic external auditory canals, draining tympanic membrane perforations or mastoid cavities, or dermatologic problems of the external canal, and who cannot or will not undergo surgical correction
- Single-sided deafness not amenable to rehabilitation using a conventional aid in the affected ear
- For either indication, a word recognition score better than 60%, and stable bone average pure tone thresholds in either ear of at least 45 dB or less for the ear-level processor and 60 dB or less for the body-level processor
In patients with bilateral atresia, bilateral bone-anchored hearing aids (BAHAs) offer improved sound localization and hearing in noise.

Preoperative Considerations

- In all patients, the BAHA simulator (test band or test rod with attached BAHA) should be offered for trial prior to proceeding with surgery so as to ensure appropriate hearing expectations.
- The option for use of a bone-conducting hearing aid in atretic ears and a contralateral routing of signal or bilateral contralateral routing of signal (CROS/BICROS) device in single-sided deafness should be offered.
- Any dermatologic conditions involving the postauricular skin on the surgical side should be treated and cleared prior to surgery to minimize the risk of implant infection postoperatively.

Surgical Technique

- The procedure may be performed on an outpatient basis under local anesthesia with or without sedation, or general anesthesia, depending on patient preference. The latter is preferred in children.
- Perioperative antibiotics may be used, but they are not essential.
- The placement site of the abutment is at the level of the linea temporalis or zygomatic root, ~55 mm diagonally above and behind the external auditory canal. A measuring template is provided by the manufacturer for incision planning. Particular attention is given to the level of implant placement in patients who plan to wear hats postoperatively. In this case, the implant should be low enough to avoid contact between the coupled external sound processor and the hat so as to avoid acoustic feedback. A dummy processor is also available to confirm implant placement at this stage.
- Hair within a 20 mm radius of the implant site is shaved, and the ear is prepared and draped in the standard fashion for ear surgery.
- An inferiorly based skin flap is designed, with the implant site centered within the proposed flap (Fig. 27–1). One percent lidocaine with 1:100,000 epinephrine is then injected subcutaneously and deep to the periosteum in an even manner around the flap site. This allows for leveled placement of the dermatome for the next step.
- A dedicated dermatome is available through the manufacturer for creation of a skin flap of standard width and depth. This obviates the need for manual thinning of the skin flap and removal of hair follicles in the area.
- A horizontal skin incision is made superficially along the upper edge of the skin flap to engage the dermatome. Mineral oil is applied over the skin. Steady downward pressure is then applied as the dermatome is used to create a 40 mm long flap. A surgical assistant would be helpful at this point to grasp the elevated edge of the flap away from the dermatome and provide countertraction of the skin away from the dermatome inferiorly. At the inferior limit of the skin flap, the dermatome is turned off before the skin flap is eased out of the dermatome to avoid transecting the flap. The skin is then kept damp with a moist gauze.
Subcutaneous tissue under the skin flap is excised down to the periosteum. The skin edges surrounding the flap are undermined to a distance of 10 mm, especially along the superior margin, to provide a smooth soft tissue contour, as well as to prevent contact between the sound processor and surrounding soft tissues postoperatively.

After hemostasis using Bovie electrocautery, a dime-size area of periosteum, centered on the implant site, is incised and removed using a periosteal elevator.

A low-speed drill provided by the manufacturer (Cochlear Americas, Denver, CO), with 3 and 4 mm burrs, is used to drill a hole in the skull bone at 1500 to 2000 rpm. A countersink hole is then created. Generous irrigation is used to avoid thermal trauma to the surrounding bone and clear out any bone dust.

The skin flap is held back in position, and a hole corresponding to the drilled hole is punched through the skin to allow for penetration of the abutment through the skin.

The titanium fixture is then secured to the drill. At a velocity of 8 to 15 rpm, the self-tapping fixture is secured into the drill hole. The drill will automatically stop as soon as the fixture is tightly secured within the hole. A wrench and screwdriver are also provided by the manufacturer to tighten the fixture if necessary. Ensure that the flange is completely sunken within the countersink hole.

The skin flap is folded over the titanium fixture and reapproximated in a single layer using a running 5–0 nylon suture. The skin puncture usually needs to be slightly enlarged to fit over the fixture. At regular intervals, the suture is passed through the underlying periosteum to ensure that the skin flap heals flush against the underlying periosteum. Additional tacking sutures may be placed in the center of the flap for the same reason.
A nonadhesive dressing is then applied over the skin flap and secured in place by snapping the BAHA healing cap onto the fixture. Over this, a loose mastoid dressing may be applied for 24 hours.

Postoperative Care

Topical antibiotics are applied to the incision daily until the sutures are removed on postoperative day 10. After that, soap and water may be used to gently clean the fixture site daily. When healing is complete, a soft toothbrush may be used daily to clean around the fixture.

The sound processor is fitted 6 to 12 weeks after surgery when osseointegration is complete.

Pearls and Pitfalls

If the sigmoid sinus or middle fossa dura are encountered when drilling the fixture hole, the site may still be used unless bleeding cannot be controlled or dura is violated and cerebrospinal fluid drainage through the screw hole is evident. In this case, the hole should be sealed with bone wax and a secondary screw placement site identified.

In very well aerated mastoids, air cells may be encountered during drilling. As long as there is adequate bone to secure the BAHA fixture, the hole may be used.

A loose fixture is the most common cause of local skin reactions around the fixture site. This may be checked manually using instruments provided by the manufacturer during or after surgery (Cochlear Corporation, Denver, CO).

One should err on extensive undermining of the soft tissues adjacent to the skin flap. This is particularly important along the gravity-prone superior edge of the skin flap, which tends to prolapse inferiorly with time, especially in individuals with thick scalp tissue.

Meticulous personal hygiene is critical in minimizing the risk of local infection with skin-penetrating implants.

Pain at the fixture site long after healing is complete should alert the physician to a loose fixture.

Complaints of hearing deterioration after prolonged use of the BAHA device may be secondary to progression of cochlear loss, loss of osseointegration, or sound processor dysfunction.

Cochlear Implants

Device Components

Internal receiver/stimulator with cochlear electrode array, with or without ground electrode

External ear-level behind-the-ear (BTE) or body-level sound processor
Indications for Implantation

- Bilateral severe to profound sensorineural hearing loss with no benefit using conventional hearing aids.
- Audiologic testing to establish cochlear implant candidacy is necessary for both adults and children. The full protocol of test procedures and criteria for patient selection is specified by the U.S. Food and Drug Administration and detailed in literature provided by the individual implant manufacturers. As these criteria continue to evolve, the trend is toward implanting individuals with increasingly more residual hearing.
- Prelingually deafened adults with minimal speech and language skills are generally poor candidates for implantation.
- The current lower age limit for implantation is 12 months of age, although earlier implantation is reasonable and prudent in postmeningeitc children who risk developing cochlear ossification over time.

Preoperative Considerations

- Imaging  High-resolution computed tomography (CT) imaging of the temporal bone is helpful in delineating cochlear and facial nerve anatomy. Although cochlear ossification is not a contraindication to implantation, the need for modified implant electrodes or surgical technique should be established preoperatively. Magnetic resonance imaging (MRI) using high-resolution T2 sequences has now become the imaging modality of choice for evaluating cochlear ossification and soft tissue obliteration of the cochlea. Additionally, sagittal reconstructions of the internal auditory canal may be used to detect cochlear nerve agenesis.
- Promontory stimulation  Not routinely used by all implant teams; may be helpful if central hearing loss is suspected.
- Selection of ear to be implanted  This remains a controversial subject and beyond the scope of this chapter. In general, if the patient has some aidable hearing in one ear, an effort is made to implant the contralateral ear, so that the patient can continue to use a hearing aid in the better hearing ear and the implant in the other.
- Antimicrobial coverage  Preoperative vaccination against streptococcal pneumonia is now routinely recommended. Broad spectrum antibiotics are used perioperatively by most surgeons.
- Other considerations  Psychological evaluation, speech language evaluation, counseling, and family support may be required preoperatively.

Surgical Technique

- Surgery is performed under general anesthesia, following the routine standard preparation for postauricular transmastoid surgery.
- Intraoperative facial nerve monitoring is routinely employed.
- Multiple incisions have been used for surgical exposure, the most common being the curvilinear incision above and behind the auricle and the lazy-S incision.
Surgeon preference and device type are primary factors influencing the type of incision used. The incision should not run across the receiver-stimulator.

- A stair-stepped incision is made through the temporalis muscle/fascia and peristeum to expose the mastoid cortex and parietal skull, creating an anteroinferiorly based musculoperiosteal flap, which will at least cover the transition zone between the receiver-stimulator and carrier electrode.

- A complete mastoidectomy is performed without saucerizing the superior and posterior edges of the mastoid cortex. If the size of the mastoid permits, a gutter is drilled under these edges to secure the carrier electrode within the mastoid cavity.

- The mastoid antrum is entered, the incus body is identified, and the facial recess is opened. The incus body marks the level of the facial recess. The posterior canal is thinned as much as possible to provide maximal visualization of the round window through the facial recess. The facial recess should be carefully saucerized to the limits of the chorda tympani inferiorly, the incus buttress superiorly, and the vertical facial nerve posteriorly. Removal of bone anteromedial to the facial nerve and inferiorly between the vertical facial nerve and chorda tympani is usually necessary for optimal visualization of the round window. Copious irrigation should be used when working in the facial recess to avoid thermal injury to the facial nerve. The drill should be turned on and off before moving in and out of the facial recess. Attention should also be directed to the shaft of the burr to ensure that inadvertent injury to the vertical facial nerve is avoided when drilling through the facial recess. If the facial recess is prohibitively small, the chorda tympani nerve may be mobilized or sacrificed. Because this nerve exits at the level of the fibrous annulus, care should be taken in further lateral dissection to avoid violating the external auditory canal at this juncture.

- The patient is then rotated toward the surgeon to visualize the round window, which lies posterior and inferior to the oval window. The bony overhang of the round window niche is carefully drilled down using a 1 mm diamond burr. This allows full visualization of the round window membrane.

- Prior to performing the cochleostomy, the bony well for placement of the receiver-stimulator is created posterosuperior to the mastoid cavity. In children, a thin skull may necessitate bony exposure down to the dura. If further depth is required, a bony island is left in the center of the well to protect the underlying dura. A bony trough is created between the well and the mastoid cavity for placement of the carrier electrode. Suture holes may be drilled alongside the bony well at this point if the device is going to be secured using suture ties.

- The implant electrode may be inserted directly through the round window membrane or through a separate cochleostomy created anteroinferior to the round window membrane, into the scala tympani, using a 1.0 to 1.5 mm diamond burr. The latter offers the advantage of a straight trajectory for electrode insertion. The drill should be directed toward the patient’s nose to avoid injury to the basilar membrane and osseous spiral lamina superiorly, and entry into hypotympanic air cells inferiorly.

- Options for ossified cochleas:
  - Drill through the short ossified segment laterally into the patent distal scala tympani.
Electrode insertion into patent scala vestibuli
Dual cochleostomy into basal and apical turns of the cochlea, with insertion of a split electrode array
Perform canal wall down mastoidectomy, blind sac closure of external ear canal, and drill a trough around the modiolus to seat the electrode.

Monopolar electrocautery is disconnected after hemostasis is secured. Once the implant device is in place, only bipolar electrocautery should be used to avoid the possibility of electrical current conduction through the receiver.

The receiver-stimulator is seated within the bony well, secured in place with non-absorbable sutures prior to electrode insertion. The electrode is gently inserted through the facial recess into the cochleostomy according to the particular manufacturer’s technical guidelines. If resistance is encountered, the surgeon should reassess electrode placement. Lubricants, such as Healon, are used by some surgeons to facilitate electrode insertion. The extracochlear electrode is secured using small pieces of temporalis muscle or fascia at the cochleostomy site. This encourages subsequent scar tissue formation, which will seal the cochleostomy long term and minimize the risk of infectious complications and electrode extrusion. The carrier electrode is anchored under the lateral mastoid cortical ledges. The ground electrode, if applicable, is buried under the temporalis muscle anterosuperiorly.

If the surgeon is not certain of correct electrode placement within the cochlea, an intraoperative anteroposterior transorbital plain x-ray is obtained and reviewed prior to wound closure.

The wound is closed in two layers. Every effort is made to close the musculoperiosteal flap in such a manner that it isolates the carrier electrode within the mastoid cavity and covers the transition zone between the receiver-stimulator and carrier electrode. Intraoperative neurophysiologic monitoring is completed at this time, if desired.

A mastoid dressing is applied over the ear and left in place for 24 hours.

Postoperative Care

Overnight observation in the hospital is recommended for young children and adults experiencing severe dizziness after surgery.

The patient is fitted with the external processor 4 weeks after surgery.

Postoperative wound infections are aggressively managed with broad-spectrum antibiotic administration.

Postoperative dizziness and/or disequilibrium may occur but usually resolve in weeks to months. If necessary, the patient may be enrolled in vestibular rehabilitation therapy to accelerate recovery. The routine use of vestibular suppressants is not encouraged because this will delay recovery.

Pearls and Pitfalls

Slight variations in surgical technique may be required for different devices. The surgeon should familiarize himself or herself with the particular manufacturer’s guidelines for surgical technique.
A backup device should always be available at the time of surgery in the event that the implanted device fails to function.

Compressed short and double electrode arrays may be necessary for the ossified cochlea.

In individuals with chronic otitis media, perforations of the tympanic membrane in the implanted ear should generally be repaired and well healed (4–6 months) prior to proceeding with cochlear implantation. If implantation is necessary in an ear with a canal wall down cavity, blind sac closure of the external auditory meatus and obliteration of the mastoid cavity are recommended. If no active infection is detected, this may be performed in a single stage, along with implant insertion.

Minimal access incisions should be used only by experienced implant surgeons.

Any violation of the bony external auditory canal at the time of surgery should be repaired with hydroxyapatite or bone pate.

Cerebrospinal fluid leakage should be anticipated in congenitally malformed inner ears. This may be controlled with head elevation and local packing at the cochleostomy site. The eustachian tube may also be occluded at the time of surgery. Lumbar drainage is rarely necessary.

Postoperative facial palsy, if immediate, should be explored to determine the extent of nerve injury. Principles of decompression and repair of the facial nerve in this setting are as described in Chapter 28. Delayed paresis implies an intact nerve. Observation and treatment with systemic steroids, and possibly antiviral medication, are generally recommended.

Bilateral cochlear implantation is currently being offered to both children and adults to provide the benefits of binaural hearing, including improved sound localization and hearing in noise.
Facial Nerve Decompression and Repair

Elizabeth H. Toh and Barry E. Hirsch

The primary goal of facial nerve decompression with or without repair is to optimize functional recovery following facial nerve trauma or inflammation. Decompression is offered only when surgery improves functional outcome relative to observation and medical management alone.

◆ Facial Nerve Decompression

Indications for Surgery

◆ Surgical decompression of the facial nerve is indicated for acute facial palsy resulting from:
  ◦ Bell’s palsy
  ◦ Chronic otitis media with cholesteatoma
  ◦ Iatrogenic facial nerve trauma
  ◦ Temporal bone trauma with immediate facial palsy or bony spicule compression visualized on computed tomography (CT) imaging
  ◦ Facial neuroma with early facial weakness

◆ With Bell’s palsy, the site of nerve entrapment appears to be within the labyrinthine segment of the nerve. Decompression of this segment alone through a middle fossa craniotomy is adequate when electrical criteria are met.

◆ With chronic ear disease and iatrogenic trauma, decompression of the suspected site of nerve compression (usually tympanic and mastoid segments) is usually possible through a standard transmastoid approach. Nerve repair may also be necessary in iatrogenic trauma if the nerve has been partially or totally transected.
The most common site of trauma in temporal bone fractures is in the perigeniculate area. Involvement of the nerve medial to the geniculate ganglion will necessitate a combined transmastoid middle fossa approach for complete decompression.

Delayed onset facial weakness after trauma is due to edema and secondary entrapment neuropathy, and usually recovers without surgical intervention.

The rationale behind facial nerve decompression without tumor resection in the management of facial neuromas is based on the anticipated immediate postoperative facial paralysis with incomplete recovery following neurorrhaphy, even in the best case scenario. As such, decompression affords the patient continued normal or near-normal facial function, until progressive tumor growth results in significant facial weakness equivalent to the best anticipated functional recovery with neurorrhaphy.

Preoperative Considerations

- **Electrical testing of the facial nerve** Electroneurography (ENoG) and electromyography (EMG) are used to determine surgical candidacy when no clinical function is appreciable with Bell’s palsy and with immediate facial paralysis following temporal bone trauma. Between days 3 and 10 following onset of complete paralysis, if ENoG testing indicate 10% or less muscle function on the affected side relative to the normal side, and voluntary motor unit action potentials are absent on EMG testing, surgical decompression may be offered.

- **Temporal bone imaging** High-resolution axial and coronal CT imaging of the temporal bone using bone algorithms is indicated primarily for temporal bone trauma. Magnetic resonance imaging (MRI) of the facial nerve is used to diagnose facial nerve tumors, which generally present with progressive facial palsy, with or without hyperkinesis.

- **Systemic steroids** Usually administered upon initial diagnosis of acute facial palsy (prednisone 1 mg/kg/day for 10 to 14 days).

- **Eye care** The affected eye should be aggressively lubricated and protected at the time of initial diagnosis and continued until adequate eye closure is achieved.

Surgical Technique

The choice of approach is determined by location of injury and hearing status in the affected ear.

*Middle Fossa Approach*

- Used to explore the facial nerve at and proximal to the geniculate ganglion in a hearing ear (Bell’s palsy, temporal bone trauma, facial neuromas). Patients over 60 years of age are poor surgical candidates for this approach since they tend to have thin dura which tears easily with dissection, and do not tolerate prolonged temporal lobe retraction.
The operating table is rotated 180 degrees away from anesthesia. The surgeon is seated at the end of the operating table across from the anesthesiologist and the operating microscope and scrub nurse/technician on either side of the patient. The patient should be secured to the operating table, and the endotracheal tube to the patient.

The patient is positioned supine with the head turned such that the operated ear is facing up.

Intraoperative facial nerve monitoring (in case distal facial nerve stimulation is performed intraoperatively) and auditory brainstem response monitoring is set up at the beginning of the procedure.

Perioperative medications administered at induction include broad-spectrum antibiotics with good cerebrospinal fluid (CSF) penetration (ceftriaxone), Lasix 20 mg, mannitol 0.5 mg/kg, and dexamethasone 10 mg.

A 4 × 5 cm craniotomy is marked on the skin, centered two thirds anterior and one third posterior to the external auditory canal, and based inferiorly on the root of the zygoma (approximate level of middle fossa floor).

The skin incision is begun in the preauricular crease at the level of the lower border of the zygoma, then extended superiorly above and behind the auricle to form a reverse question mark which extends superiorly to the upper craniotomy border. Anterior and posterior skin flaps lateral to the temporalis fascia are elevated to expose the temporalis muscle.

An anteroinferiorly based temporalis muscle flap is created by incising the muscle along linea temporalis using Bovie electrocautery.

A craniotomy measuring 4 × 5 cm is created in the location described above, using a 4 mm cutting burr or craniotome. The bone flap is then carefully elevated from underlying dura using a blunt dural elevator and soaked in bacitracin solution until the end of the procedure. Any bleeding from the dura at this point may be controlled with bipolar electrocautery. The inferior border of the craniotomy is lowered to the level of the middle fossa floor using a drill or rongeur.

Dura is then carefully elevated off the middle fossa floor in a posterior to anterior direction to expose the anatomy illustrated in Fig. 28–1. The limits of exposure are the middle meningeal artery anteriorly, the sulcus of the superior petrosal sinus medially, and the arcuate eminence (corresponding to the superior semicircular canal) posteriorly. Dura over the greater superficial petrosal nerve (GSPN) tends to be densely adherent to the nerve. Caution is exercised at this point in the dissection to avoid inadvertent trauma to a dehiscent geniculate ganglion. Elevating the dura in a posterior to anterior direction also minimizes injury to the GSPN and geniculate ganglion. Bleeding may be more copious in this area due to the dense vascular network supplying the perigeniculate area.

A middle fossa retractor is then wedged under the sulcus of the superior petrosal sinus medially to retract the temporal lobe.

The approximate location of the internal auditory canal (IAC) is identified using the arcuate eminence and GSPN as anatomical landmarks. This anatomical relationship is illustrated in Fig. 28–1. The IAC also lies medially along the axis of the external auditory canal. In cases where the arcuate eminence may not be evident, this axis, along with the GSPN, helps in localizing the IAC.
Using a 1 mm diamond burr and copious irrigation, bone over the labyrinthine facial nerve is carefully removed by following the GSPN posteriorly to the geniculate ganglion and continuing posteromedially just lateral to the upper basal turn of the cochlea, past the meatal foramen, and unroofing a short segment of the lateral IAC to expose Bill's bar. Because of the extreme proximity of the cochlea to the labyrinthine facial nerve, the surgeon should be on the lookout for the blue line of the cochlea to avoid fenestrating the cochlea. If the cochlea is inadvertently fenestrated, avoid suctioning in this area and immediately plug the bony defect with bone wax. Bone over the tegmen tympani is then removed to complete bony decompression of the perigeniculate facial nerve. Any further fine bony removal may be accomplished using small angled hooks.

A no. 59 Beaver blade is used to incise the periosteum and epineural sheath of the labyrinthine facial nerve.

Any open mastoid air cells are occluded with bone wax and the resultant bony defect covered with temporalis fascia. A bone flap is harvested from the inner table of the craniotomy flap for placement over the fascia to prevent herniation of dura/brain into the middle ear. The middle fossa retractor is released and removed, allowing the temporal lobe to expand back over the middle fossa floor. The remainder of the craniotomy flap is replaced and secured by reapproximating the overlying temporalis muscle.
The skin flap is then reapproximated in two layers without the use of any drains, and a firm mastoid dressing is placed over the operated ear. This is left in place for 3 days and removed prior to discharge from the hospital.

Postoperatively, the patient is closely monitored, paying particular attention to any CSF leakage from the wound or nose. Should the latter occur, placement of a lumbar drain usually resolves the problem.

Translabyrinthine Approach

- Used to decompress the facial nerve proximal to the geniculate ganglion in a non-hearing ear
- The technique for this approach is detailed in Chapter 30.

Transmastoid Approach

- Used when facial nerve decompression is only required for segments lateral to the geniculate ganglion.
- Preparation and draping are similar to that for standard postauricular transmastoid surgery. Incisions and bony exposure are also similar.
- A complete mastoidectomy is performed and bony dissection is continued anterosuperiorly, after identifying the body of the incus, to open the epitympanum and expose the incudomalleal joint. This should be completed with care using a stapes curette so as to avoid inadvertently drilling on the ossicular chain and causing sensorineural hearing loss. Attention should also be directed to the upper surface of the burr against the tegmen. If bone of the middle fossa must be removed to access the epitympanum, the resultant bony defect should be repaired with bone, cartilage, or hydroxyapatite at the end of the procedure to prevent dural herniation in the future.
- Using higher magnification, the facial recess is identified and progressively opened by following the mediolateral plane of the incus body posteriorly along the posterior canal wall, taking care not to drill lateral to the chorda tympani nerve, beyond which the external auditory canal lies. Two millimeter and smaller diamond burrs are used, along with copious irrigation to avoid thermal injury to the facial nerve. Drilling in the facial recess is performed parallel to the facial nerve.
- The mastoid segment of the facial nerve is identified posteriorly. This segment of the nerve extends from the second genu, located immediately medial and inferior to the lateral semicircular canal, to the stylomastoid foramen at the anterior end of the digastric ridge inferiorly. As it courses down the mastoid, it takes a slightly posterior and lateral course. At the stylomastoid foramen, the facial nerve is encased within a thick fibrous sheath. The entire segment of the nerve below the second genu is carefully decompressed for a 180-degree circumference anterolaterally and posteriorly using a 2 to 3 mm diamond burr with copious irrigation.
- The second genu and distal tympanic segment are then decompressed in a barber pole fashion using a 1.0 to 1.5 mm diamond burr from a posteroinferior to anteromedial direction taking care not to violate the lateral semicircular canal.
Further decompression of the proximal tympanic facial nerve typically will require temporary removal of the incus. The incudostapedial joint is separated using sharp-angled hooks through the facial recess. The incus is retrieved from the epitympanum using a hook placed under the incus body and posterosuperior traction. Proceeding anteriorly, the tympanic facial nerve runs above the oval window, then between the cochleariform process inferiorly and cog superiorly, before diving medially toward the geniculate ganglion. Bony decompression here is accomplished using microcurettes and angled picks.

Access to the labyrinthine facial nerve proximal to the geniculate ganglion through the transmastoid approach is limited by the ampullae of the superior and lateral semicircular canals, and would therefore require a combined approach through a middle fossa craniotomy.

The entire tympanic and mastoid facial nerve is carefully inspected. Any traumatic bony spicules impinging on the facial nerve are removed. The nerve sheath is opened at the site of injury, and for a short distance proximal and distal to the site of injury. If the nerve is partially (> 50% diameter of nerve) or totally transected, primary neurorrhaphy or cable grafting may be indicated (see next section).

The removed incus is replaced at the end of the procedure and supported in place using saline-soaked Gelfoam. If removal of the malleus head was necessary for surgical exposure, the incus may be sculpted and interposed between the stapes capitulum and malleus handle.

The postauricular wound is closed in layers with absorbable sutures, and a mastoid dressing is applied to the operated ear for 24 hours.

Postoperative hospitalization following transmastoid-only decompression is not necessary.

**Facial Nerve Repair**

**General Principles**

- Partial or complete transection of the facial nerve should be repaired using primary neurorrhaphy or cable grafting when proximal and distal ends of the facial nerve are accessible. Surgical options in the absence of either proximal or distal segments are discussed in detail in Chapter 29.
- Restoration of anatomical continuity of the facial nerve without tension is the primary goal of facial nerve repair.
- Repair should be performed as early as medically feasible. In the case of contaminated wounds, delayed repair within 30 days is facilitated by tagging the disrupted nerve endings at the time of primary wound exploration. Facial nerve repair after 1 year usually results in poor functional recovery.
- Use of a surgical microscope provides optimal magnification for nerve repair.
- Primary repair offers the best functional outcome, as does early repair (within 30 days of injury). Recovery can continue to progress up to 2 years following repair.
- If the anatomical status of the facial nerve is unclear or paralysis is of delayed onset, watchful waiting for up to 1 year may be reasonable.
Primary Repair

- When feasible, this is the ideal surgical option because only one anastomosis will be necessary, avoiding 2 repair sites, a devascularized nerve graft and variable diameters at the 4 ends of the anastomosed nerves.
- If a sizeable gap does not permit tension-free anastomosis, the alternative to cable grafting would be intratemporal rerouting of the distal nerve segment. This necessitates a translabyrinthine exposure, sectioning of the GSPN and chorda tympani branches, and complete skeletonization of the facial nerve within the fallopian canal to gain a maximum of 1.5 cm in length. In so doing, the blood supply to the distal nerve segment may be disrupted and further injury incurred. The advantages to facial nerve rerouting for primary reanastomosis is as indicated earlier. In addition, a sensory deficit can be avoided from the site where the donor nerve is harvested.
- Suture anastomosis of the nerve is generally not necessary within the fallopian canal in the temporal bone.
- The cut ends of the nerve are freshened by sharply trimming the endings back to normal-appearing nerve tissue. Any excess surrounding soft tissue is trimmed to allow proper identification of the nerve sheath. In delayed repairs, fibrous scarring or traumatic neuromas may be encountered at the proximal end of the cut nerve, which should be excised prior to repair.
- The authors use one or two 9–0 monofilament sutures to reapproximate the epineural layer. At the cerebellopontine angle, the lack of a resilient epineural layer may necessitate a single through-and-through suture to secure the cut ends of the nerve together. In this location, the suture is generally placed through the distal end first to avoid placing traction on and tearing the proximal end. Whichever technique is used, the goal is to ensure the best possible anatomical realignment of the cut ends.
- After suture repair, the anastomosis may be further reinforced using fibrinogen (Tisseal). The use of nerve tubes and conduits is not necessary.

Cable Grafting

- Indicated when tension-free anastomosis cannot be confidently performed.
- Most common donor nerve options
  - Great auricular nerve Up to 8 cm in length, one bifurcation, small diameter, donor site in close proximity to nerve repair
  - Sural nerve Up to 40 cm in length, robust diameter, extensive branching pattern; donor site requires separate preparation of the leg
- Selection of the donor nerve will be determined primarily by the length of graft and the axonal volume required. Other considerations include branching pattern, risk of tumor involvement of the donor nerve in malignant disease, and donor site morbidity.
The length of the graft harvested should be 1 to 2 cm longer than the measured nerve gap to be bridged.

Location of donor graft

- **Great auricular nerve**  Bisects line drawn between mastoid tip and angle of mandible and located midway between mastoid tip and clavicle along posterior border of sternocleidomastoid muscle
- **Sural nerve**  Located between lateral malleolus and Achilles’ tendon, deep or just posterior to the saphenous vein

Neural anastomosis is accomplished in a fashion similar to primary anastomosis. Within the temporal bone, cable grafts may be laid within the fallopian canal and supported with Surgicel, Gelfoam, or fibrinogen, without suture anastomosis.

Functional outcome does not seem to be related to nerve graft length, but nerve grafts placed distal to the meatal foramen appear to do better. The age of the patient at the time of diagnosis does not appear to affect outcome.

**Hypoglossal-Facial Anastomosis**

- Indications and technique are detailed in Chapter 29.
Facial Reanimation

Barry M. Schaitkin

Rehabilitation of the patient with chronic facial paralysis must take into account the losses of form and function. Although each individual presents unique challenges, experience has led to guidelines in caring for this group of patients.

◆ Assessment and Planning

The patient with facial paralysis must be treated by the physician on an individual basis, and only after extensive evaluation of the patient’s deficits and desires. The assessment should include evaluation of the:

◆ Cause of the facial paralysis
◆ Extent of paralysis and functional deficit(s)
◆ Likelihood and time course to recovery from facial paralysis
◆ Presence of other cranial nerve deficits
◆ Patient’s life expectancy
◆ Duration of paralysis
◆ Patient’s needs and expectations

◆ General Principles

Past experience gained by careful evaluation of postoperative results suggests the following key points:

◆ The facial muscles, if available, should be reinnervated as early as possible.
The upper and lower face should be reanimated separately to avoid mass movement. Combining both static and dynamic procedures often gives the best results. Each procedure is individualized to the patient’s deficit.

**Dynamic Reanimation Procedures**

Dynamic procedures can be divided into three broad categories. The facial nerve nucleus (proximal system) and the facial nerve musculature (distal system) are thought of as two structures, which ideally are in continuity. The procedures are then dictated by the integrity of those systems:

- Proximal system intact and distal system intact
- Proximal system intact and distal system unavailable
- Distal and proximal systems unavailable
- Proximal system not available and distal system intact

**Proximal and Distal Systems Intact**

- This situation can be illustrated by the patient with an iatrogenic facial nerve deficit caused during a mastoidectomy. With both systems intact, the ideal procedure reconstitutes the deficit with a primary neurorrhaphy, or more likely a nerve graft.
- Key point: The ideal reanimation procedure reconstitutes the facial nerve nucleus with the facial nerve musculature.
- Technical points on nerve grafting:
  - Choose the appropriate nerve graft for length and axon volume.
  - Minimal number of 9–0 monofilament sutures to approximate endoneurial surfaces
  - Do repair under microscope; high power to place sutures, low power to tie them.
  - No suture required within the temporal bone
  - No tension along nerve course

**Proximal System Intact and Distal Unavailable**

- The patient who has undergone radical surgery for a parotid malignancy with the distal nerves sacrificed is in this category. If the patient is a candidate for and desirous of a dynamic procedure, and if that person understands the risks, options, and benefits, the proximal facial nerve should be used to innervate a free muscle transfer.
- Choose muscle based on:
  - Need for skin if dermis is invaded by cancer
  - Need for bulk
  - Length of pedicle
If only muscle is needed, the best choices are the gracilis or pectoralis minor.

Free muscle is anchored to the modiolus to give an active smile.

If powered by the facial nerve, no reeducation is necessary.

Some degree of static support should be provided. Graft may not be completely functional before 18 months.

Static support should be exaggerated, which will decrease over 6 weeks.

Tendon-type repair with permanent suture at modiolus is done to prevent dehiscence.

Both Proximal and Distal Systems Unavailable

Free muscle can be powered by:

- Hypoglossal jump graft
- Cross-facial nerve graft
- Third division of the trigeminal nerve

Proximal System Unavailable and Distal System Intact

A patient who has a permanent facial paralysis after acoustic tumor surgery may be in this category. Ideally, however, this patient would be treated with a nerve interposition graft, as noted in the key point above. Unfortunately, patients rarely have this performed during the initial setting and are reluctant to have a second intracranial procedure.

If the nerve cannot be reconstituted, nerve substitution is the procedure of choice.

Classically, the entire hypoglossal nerve was used for nerve substitution. This resulted in eye closure, facial tone, and facial symmetry at rest in over 90% of patients. Attempts at preservation of tongue function by retrograde dissection of the hypoglossal nerve or by using the descendens hypoglossi were abandoned because of poor results.

May introduced the hypoglossal-facial interposition jump graft as a means of achieving facial reanimation without sacrificing tongue function. This procedure should be done as soon after injury as possible. The jump graft works best when performed in the first 6 months, and results fall off dramatically after 1 year.

A jump graft is an end-to-side anastomosis of the facial nerve into the hypoglossal nerve.

This is not to imply that there is no benefit in doing a procedure late within the ideal time frame. Many patients will look dramatically better if at least tone is preserved, and it will give the reanimating surgeon something on which to build.

Key point: Nerve graft procedures should always be done as soon as possible, as results decay after 6 months.

Patients undergoing dynamic procedures may also benefit from static procedures or from combination with a temporalis muscle transposition.

Young patients reanimated early with a dynamic procedure usually do not require eye reanimation.
Muscle transposition can augment the results of nerve graft or substitution when:

- The patient has skin changes of aging.
- The nerve graft is done late in the ideal time frame.
- It is too late to do a nerve graft or prognostic conditions preclude neural procedures.2

Additional Considerations

Procedures for Paralytic Eyelids

- Careful and complete ophthalmologic evaluation is required.
- The level of the eyebrows and the position of the lower eyelids must not be ignored.
- Lacrimal function should be assessed.
- The degree of eyelid approximation with gentle closure, blink, and forceful closure are evaluated.
- Patients should be particularly scrutinized for the possibility of the BAD syndrome as described by Guibor as being the lack of Bell’s phenomenon, corneal anesthesia, and dryness.2

Surgical Technique of Eye Reanimation: Special Considerations

- Tarsorrhaphy is no longer the gold standard for eye reanimation. This causes cosmetic blight and provides no active eye closure.
- The gold weight, although imperfect, has become the standard because of its ease of insertion, durability, and low complication rate.
- Gold weights are selected based on their function when taped to the upper lid. Ideally, let the patient wear it for a full day to assess eye fatigue. Weights not made of gold are available for this purpose.
- The 1 g weight is most commonly used with adults.
- The weight is placed in a pocket created lateral to the tarsus.
- Use three-point 8–0 monofilament nylon fixation.
- The weight should be centered nasally to the midpupillary line.
- If the weight required to provide closure causes significant ptosis, a palpebral eye spring should be inserted. The spring provides a more dynamic and functional result but has been difficult for surgeons to master because it:
  - Has to be custom made by the surgeon
  - Is technically difficult to form
  - Is easy to overcorrect with pseudoptosis
  - Has extrusion issues at pressure points
  - Can have breakage of the spring after 10 years
Motor Sensory Reeducation

Patients are referred for motor sensory reeducation when:

- The facial nerve has been repaired.
- Reanimation surgery has been completed.
- Full spontaneous recovery is not expected.
- Synkinesis is present.
- Facial asymmetry is present.

Pearls and Pitfalls

- In patients whose facial nerve cannot be reconstituted, the tendency of the surgeon is to perform a cross-facial graft. The results of this procedure have not been as satisfactory because of the limited axonal power that is transmitted through the graft.
- For many years tarsorrhaphy and full hypoglossal-facial nerve substitution were the standards of facial reanimation. However, a better cosmetic and functional result can be achieved with individual tailoring of the patient’s deficit using multiple procedures within the modern facial reanimation surgeon’s armamentarium.
- Eyelid procedures, which address both the upper and lower eyelid as well as the lacrimal system, can restore the eye to a reasonable level of function.
- Ideally, the facial nerve is always reconstituted. The hypoglossal jump graft has become a good substitution when employed early.
- The patient must be made aware preoperatively that normal, animated, symmetrical, independent function is still beyond our grasp.

References

Surgery for Acoustic Neuromas

Elizabeth H. Toh

There are three basic surgical approaches for resection of acoustic neuromas. The approach selected is dependent on tumor location, tumor size, and hearing status of the affected ear. The middle fossa and retrosigmoid approaches offer the potential for hearing preservation, whereas the translabyrinthine approach necessarily sacrifices any residual hearing in the affected ear. Surgery is usually performed with neurosurgical support for intracranial tumor dissection.

◆ General Considerations

◆ Surgical removal is the preferred treatment modality for large acoustic neuromas. For small growing tumors, surgery offers the option for potential long-term hearing preservation with complete cure.

◆ Hearing preservation approaches are offered if the patient has any aidable residual hearing in the affected ear (pure tone average threshold better than 50 dB and word recognition score over 50%). Strict audiologic criteria for useful hearing may vary with different centers.

◆ Treatment alternatives, including observation with serial imaging, stereotactic radiation, and, occasionally, tumor decompression only for (neurofibromatosis 2[NF2] patients) should be extensively discussed with the patient prior to surgery.

◆ The overall health status, age, and preferences of the patient should be taken into consideration, along with tumor characteristics, in selecting the best treatment modality for each individual patient.
Preoperative Considerations

Audiometric Evaluation

- A complete pure tone and speech audiogram should be obtained prior to surgery. Although auditory brainstem response testing may be helpful in prognosticating postoperative hearing, it is not routinely performed.

Imaging

- A gadolinium-enhanced magnetic resonance imaging (MRI) scan of the internal auditory canals is the gold standard for diagnosing acoustic neuromas. Care should be taken to review the unenhanced T1 images to rule out the rare lipoma.
- Additional MRI of the entire spine should be routinely performed in all NF2 patients.

Vestibular Testing

- Caloric testing may be helpful in predicting postoperative dizziness. The greater the extent of reduced vestibular response in the affected ear, the less likely the patient is to be dizzy after surgery. This, however, assumes a superior vestibular nerve origin for the tumor, which may not always be the case.

Operative Considerations

- Surgery is performed under general anesthesia, with the use of muscle relaxants limited to the initial induction phase only.
- Intraoperative facial nerve monitoring is routinely used. Brainstem evoked audiometry responses are monitored in hearing preservation approaches only. The additional monitoring of somatic sensory evoked potentials is optional for small tumors but helpful with surgery for larger tumors.
- The middle fossa and translabyrinthine approaches may be performed without the use of a Mayfield holder and pins. The retrosigmoid approach is usually performed using head pins for positioning.
- The left lower quadrant of the abdomen is also prepared and draped at the beginning of the procedure to harvest an abdominal fat graft.
- Perioperative medications administered at the time of anesthesia induction include broad-spectrum antibiotics, steroids, and diuretics (Lasix/mannitol).
- A Foley catheter, nasogastric tube, and Venodyne boots (Microtek Medical Inc., Columbus, Mississippi) are used for every case.
- Bacitracin irrigation is used only after bony dissection has been completed because bothersome foaming will occur if used in the irrigation fluid for drilling.
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◆ Translabyrinthine Approach

Indications

◆ Any size tumor with no useful hearing in the affected ear.
◆ Larger tumors filling the internal auditory canal (IAC) and extending more than 1 cm into the cerebellopontine angle (CPA), regardless of hearing status, because hearing preservation is unlikely using any approach in such cases.

Surgical Technique

◆ A large postauricular C-shaped incision is made 3 to 4 cm behind the ear after the incision is injected with 1% lidocaine with 1:100,000 epinephrine solution. This incision is slightly posterior to the standard postauricular incision for chronic ear surgery, so as to allow for exposure of the retrosigmoid dura.
◆ The skin flap is elevated in the soft tissue plane superficial to the temporalis fascia superiorly and the mastoid periosteum inferiorly. The periosteum is then incised and elevated separately. This allows for a layered wound closure.
◆ A complete mastoidectomy is performed. The vertical facial nerve is carefully skeletonized to the stylomastoid foramen, at the anterior end of the digastric ridge. Bone over and behind the sigmoid sinus, posterior fossa dura, and middle fossa dura is carefully removed. Retrosigmoid dural exposure allows for posterior retraction of the sigmoid to increase surgical exposure. A bony island may be left over the sigmoid sinus to protect the sinus from the shaft of the drill when deeper drilling is performed through the labyrinth and around the IAC. Bone extending anteriorly from the sinodural angle, at the junction of the middle and posterior fossa dura, should be removed carefully because the superior petrosal sinus lies in this location.
◆ A complete labyrinthectomy is then performed. Sequential fenestration and removal of the semicircular canals (lateral, posterior, then superior canals) may be helpful in maintaining anatomical orientation to the IAC. The ampulla of the posterior canal marks the inferolateral limit of the IAC. Similarly, the ampulla of the superior canal defines the superolateral limit of the IAC. The endolymphatic duct and sac are encountered as dissection is carried through the common crus.
◆ The next step is bony decompression of the IAC. The IAC is circumferentially exposed for 270 degrees, leaving only the anterior wall of the IAC. The jugular bulb inferiorly defines the lower limit of bony dissection below the IAC. The cochlear aqueduct marks the anterior limit of the bony dissection below the IAC. The pars nervosa, containing cranial nerves IX, X, and XI, lies just anteroinferior to the cochlear aqueduct. Superiorly, the ampulla of the superior semicircular canal is innervated by the superior vestibular nerve. This marks the superolateral limit of the IAC. Bone is carefully removed in this area to expose Bill’s bar (vertical crest), which separates the superior vestibular nerve from the facial nerve as it exits the IAC. Extensive bony dissection is usually necessary to expose the medial IAC for surgical access to the tumor at the porus acusticus and within the CPA.
The facial nerve must be positively identified in the lateral IAC and labyrinthine segment, and separated from the superior vestibular nerve. The posterior fossa dura is then incised along the inferior aspect of the IAC and over the posterior fossa to provide intradural access to the tumor.

A facial nerve stimulator is often used to identify the facial nerve as it drapes over the tumor. Using a combination of blunt and sharp dissection, the tumor is carefully removed from the facial nerve. In the case of larger tumors, intracapsular debulking using a mechanical or ultrasonic debrider will ease tumor dissection from surrounding neurovascular structures.

Wound closure is generally accomplished using a combination of dural reapproximation, abdominal fat graft packing, and layered soft tissue closure. The incus is removed to allow for obliteration of the eustachian tube and middle ear with temporalis muscle. Dural grafts and tissue seals may be used to further reinforce dural closure.

Pearls

This surgical approach provides the most direct access to the CPA and provides complete access to the facial nerve along its intratemporal course if nerve grafting is anticipated.

Maximal bony exposure is obtained by aggressive removal of bone over the posterior fossa dura, particularly in the retrosigmoid area and over the middle fossa dura.

Facial nerve preservation is dependent on clear identification of the nerve laterally as it exits the IAC and medially as it exits the brainstem anteromedial to the cochleovestibular nerve. The course of the nerve over the tumor is variable and may be identified both visually and with the help of intraoperative stimulation.

Blood vessels along the surface of the tumor should be preserved where possible without coagulation.

Middle Fossa Approach

Indications

Hearing ear with small tumor located primarily within the IAC and no more than 1 cm extension into the CPA.

Elderly patients over 65 years of age generally do not tolerate temporal lobe retraction and are therefore poor candidates for this approach.

Surgical Technique

The surgeon is seated at the end of the operating table. The patient is positioned supine with the head turned with the tumor side facing up.

A straight or gently curved incision is made, beginning in the pretragal area and extending superiorly above the ear. The length and curve of the incision take into account soft tissue exposure necessary for a 5 × 5 cm craniotomy above the ear.
The lower limit of the craniotomy is at the level of the root of the zygoma, two thirds anterior and one third posterior to the external auditory canal. An anteroinferiorly based temporalis muscle flap is elevated to expose the underlying temporal bone.

- The bone flap may be elevated using a cutting burr or craniotome. Care should be taken to avoid injury to the underlying dura during this procedure.
- Dura is elevated off the floor of the middle cranial fossa posteriorly and medially to the petrous ridge, and anteriorly to the middle meningeal artery as it passes through foramen spinosum. Dissection should be performed in a posterior to anterior direction. The dura tends to be adherent along the greater superficial petrosal nerve (GSPN), and in some individuals, the geniculate ganglion may be dehiscent. Bleeding is often encountered in this area and should be carefully controlled with Surgicel packing.
- A House-Urban or similar retractor is used to maintain exposure of the middle fossa floor. The tip of the retractor should be wedged medial to the petrous ridge to maintain medial exposure of the IAC and cerebellopontine cistern. For larger tumors with anterior extension, division of the superior petrosal sinus and incision of the tentorium will provide further exposure for tumor dissection and removal (extended middle fossa approach).
- The IAC may be localized using several anatomical landmarks:
  - The axis of the IAC is approximately in line with the axis of the external auditory canal.
  - The IAC lies along the line bisecting the GSPN and arcuate eminence (which corresponds, in most cases, to the location of the superior semicircular canal).
  - The GSPN may be traced posteriorly to the geniculate ganglion. From here, the labyrinthine facial nerve is followed posteromedially into the IAC.
- Laterally, the IAC is bounded anteriorly by the basal turn of the cochlea, posteriorly by the vestibule and ampulla of the posterior semicircular canal. In this location, the roof of the IAC may be safely uncovered for only a 90 degree circumference. For this reason, the IAC should be initially identified medially, where it may be safely dissected for 270 degrees, leaving only the anteroinferior floor of the IAC (around the cochlear nerve) intact. Bony dissection is then continued medially, until Bill’s bar (separating the facial nerve anteriorly from the superior vestibular nerve posteriorly) is positively identified. The proximal half of the labyrinthine facial nerve should also be carefully decompressed. Most of this bony dissection should be performed using a diamond bur and continuous suction-irrigation.
- Once bony exposure has been completed, dura over the superior vestibular nerve is incised to expose the contents of the IAC. The superior vestibular nerve is separated from the facial nerve in the lateral IAC and sharply divided.
- Tumor dissection is performed from a medial to lateral direction to minimize traction injury to the cochlear nerve and its blood supply.
- Any exposed mastoid air cells along the floor of the middle fossa or the margins of the craniotomy should be sealed using bone wax. The dural and bony defects in the IAC incurred during the procedure are plugged using abdominal fat. The retractor is then removed, the temporal lobe is allowed to reexpand over
the middle fossa floor, and the bony plate is replaced. A surgical drain is usually left in place for 24 hours under the bone flap. Some surgeons advocate rigid fixation of the bone flap using plates and screws.

- The soft tissue flaps are reapproximated in layers, and a sterile mastoid dressing is left in place for 3 or 4 days. The dressing is generally replaced on day 1 to allow for removal of the surgical drain.

Pearls

- A clear understanding of the middle fossa bony anatomy is critical for successful bony dissection, while limiting injury to the surrounding neurovascular structures.
- The IAC should always be identified medially at the petrous ridge, prior to lateral dissection, to minimize injury to the cochlea and vestibule/ampulla of the superior semicircular canal.
- Diamond burrs used in the forward and reverse direction for bony exposure of the anterior and posterior IAC, respectively, minimize risk of trauma to the contents of the IAC in the event that the burr slips.
- Inferior vestibular nerve tumors pose a greater surgical risk to both facial function and hearing. If the inferior vestibular nerve is not involved with tumor, it may be left in situ.

Retrosigmoid Approach

Indications

- Hearing ears with tumor located primarily within the CPA, with or without lateral extension into the medial two thirds of the IAC. The superior semicircular canal limits bony exposure of the lateral one third of the IAC through this approach.
- Large tumors (>3 cm). Hearing preservation is unlikely with tumors of this size. As such, both the retrosigmoid and translabyrinthine approaches may be used in these cases.

Surgical Technique

- Surgery may be performed with the patient supine, supine lateral with the operated ear facing up, or in a seated position. The choice is based on neurosurgical preference. A Mayfield head holder is used for head positioning. Optimal positioning usually necessitates placement of a shoulder roll on the operated side so that excessive neck flexion may be avoided. In addition to cervical spine complications, overflexion of the neck may compromise circulation through the vertebral arteries, causing cerebellar edema.
- A straight or curvilinear incision is made ~3 cm behind the postauricular crease and extended down through the underlying muscles to bone. The cervical muscles are detached anteriorly and posteriorly to expose the mastoid and suboccipital skull, including the mastoid tip.
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- A 4 to 5 cm square craniotomy is made behind the sigmoid sinus and below the transverse sinus. Any visible mastoid air cells along the margins of the craniotomy are sealed with bone wax to prevent postoperative cerebrospinal (CSF) leak through the mastoid air cell system. Any bleeding bone encountered at this time may also be sealed using bone wax.

- A posteriorly based dural flap is developed behind the sigmoid sinus and below the transverse sinus to enter the intracranial space.

- CSF is drained from the cisterna magna by gently retracting the cerebellum superiorly and incising the arachnoid of the cistern. This maneuver will decompress the posterior fossa and allow the cerebellum to fall away medially. Aggressive retraction of the cerebellum without draining the cistern may result in cerebellar swelling.

- Bony exposure of the IAC is generally accomplished early to minimize the amount of bone dust collecting within the subarachnoid space, which may contribute to postoperative aseptic meningitis and headaches. Dura over the posterior face of the petrous temporal bone is incised along the axis of the IAC, and superior and inferior dural flaps are elevated. Care should be taken not to violate the sigmoid sinus laterally and the jugular bulb inferiorly. Bone behind, above, and below the IAC is removed for a 270 degree circumference along the medial two thirds of the canal. Inferiorly, the jugular bulb defines the limit of bony dissection under the IAC. Laterally, the vestibule and common crus limit bony dissection if hearing preservation is intended. The vestibular aqueduct serves as a helpful lateral landmark for bony IAC dissection. If tumor within the IAC extends farther laterally, dissection may be carefully performed using angled endoscopes. Superiorly, bony exposure must proceed cautiously to avoid inadvertent injury to the facial nerve along the anterosuperior portion of the IAC.

- For tumors extending into the IAC, intracanalicular tumor removal generally precedes CPA tumor removal. The IAC dura is incised to expose tumor within the canal. The IAC portion of the tumor is dissected off the facial and cochlear nerves laterally by finding the plane between the facial and superior vestibular nerves and dividing the superior vestibular nerve in this location.

- Intracapsular debulking of the CPA component facilitates identification and dissection of the brain and surrounding neurovascular structures off the tumor surface.

- Wound closure is completed in layers, including dural closure, bone flap replacement with or without fixation, and layered soft tissue closure. If the possibility of CSF leak is heightened by the presence of a very well pneumatized temporal bone, a lumbar drain may be placed postoperatively.

Pearls

- The retrosigmoid approach provides excellent exposure of the posterior fossa from the tentorium superiorly to the foramen magnum inferiorly and is therefore ideal for tumors with inferior extension toward the jugular foramen. Cranial nerves V through XI may all be visualized at their root entry zones and through their course within the cerebellopontine cistern.

- If the sigmoid sinus is posteriorly placed, a mastoidectomy may be performed and posterior fossa bone in the presigmoid area removed to allow for anterior retraction of the sigmoid sinus.
Anteromedial tumor dissection beyond the IAC through this approach may be limited by the facial and cochleovestibular nerves superiorly and the glossopharyngeal, vagus, and accessory nerves inferiorly. If surgical access to this area is necessary, a transpetrous approach is preferred.

Complications

Cerebrospinal Fluid Leak

CSF leak after surgery occurs most commonly through the nose, and occasionally through the surgical wound.

The risk of postoperative CSF leak through the surgical wound is minimized at the time of surgery using meticulous layered closure. Additionally, a firm mastoid dressing over the operated ear after translabyrinthine and middle fossa surgery is left in place for 3 days. Because CSF leak following retrosigmoid surgery is often the result of egress through peri-IAC air cells, the role of an external pressure dressing over the operated ear is not critical.

The routine use of stool softeners after surgery, along with head elevation, may also reduce the risk of CSF leak after acoustic neuroma surgery.

The prophylactic use of lumbar drains in acoustic neuroma surgery is controversial.

Management of CSF Leak

Management strategies will vary depending on the suspected site and extent of leak. Conservative strategies should be applied prior to considering surgical reexploration.

Initial measures should include reapplication of a pressure dressing over the operated ear. If CSF leak occurs through the surgical wound, bedside wound overclosure is recommended. Strict bed rest may be enforced. Placement of a lumbar drain may be useful for patients who have undergone middle fossa or retrosigmoid surgery because the application of external pressure over the wound may have little effect on CSF egress through the mastoid air cell system.

If conservative measures fail to control the leak after 72 hours, surgical exploration is indicated. The extent of surgery may vary from repacking of the mastoid defect in translabyrinthine cases to obliteration of the eustachian tube and middle ear in hearing ears. In the deaf ear, blind sac closure of the external auditory canal provides an added measure of security to control the leak.

For persistent leaks, hydrocephalus should be excluded by obtaining an unenhanced computed tomography scan of the head. If hydrocephalus is present, consideration should be given to permanent CSF shunting.
Surgery for Glomus Tumors and Carotid Paragangliomas

Jose N. Fayad

◆ Treatment options for glomus tumors and carotid paragangliomas include observation, radiation therapy, and microsurgical removal. The appropriate treatment is determined by tumor size, age of patient, presenting symptoms, and possible morbidity associated with treatment. Asymptomatic carotid body tumors in the elderly with significant comorbidities may best be observed.
◆ The treatment of choice for younger patients is surgical removal. Complete surgical removal is possible in 80% of patients. Long-term facial nerve function after surgery is good (House-Brackmann grade I or II) in 95% of patients. Approximately 20% of patients will require vocal cord augmentation or a gastric feeding tube due to aspiration. Occasionally, a patient will require a tracheostomy.
◆ Bilateral glomus vagale tumors pose a challenge and a risk of loss of both vagus nerves, possibly resulting in a fatal outcome. For this reason, when one of these lesions is very large and symptomatic, and the contralateral vocal cord is functional, the larger tumor can be treated surgically and radiation therapy considered for the second lesion. In other bilateral cases, treatment with radiation may be recommended for both tumors.

◆ Preoperative Considerations

Imaging
◆ All patients should undergo both computed tomography (CT) and magnetic resonance imaging (MRI) scans to define the vascular nature of these tumors, delineate boundaries of the lesion, and detect any related lesions.
◆ High-resolution CT (HRCT) in the axial and coronal planes, including soft tissue and bone algorithms, is the first study done. It defines the extent of the tumor.
and the relationship of the tumor to major vessels and the otic capsule. It also differentiates tympanicum tumors from an aberrant carotid or high-riding jugular bulb.

- Detection of multicentric or metastatic lesions is usually done using radionuclide scintigraphy with indium 111 octreotide. This exam is not done routinely preoperatively unless there is a high risk of multicentricity, such as in hereditary tumors.

Secreting Tumors

- Clinically significant secretion of catecholamines is identifiable in only 1 to 3% of tumors and unlikely in glomus tympanicum tumors. In secretory tumors, a search should be made for concomitant pheochromocytomas, especially if high levels of epinephrine are detected. In patients with clinical symptoms, preoperative measurement of serum catecholamine levels and 24-hour urinary metanephrines and vanillylmandelic acid (VMA) testing is performed. Management of patients with secreting tumors includes perioperative blood pressure management with blocking agents, including phentolamine and phenoxybenzamine, and intraoperative invasive hemodynamic monitoring.

Embolization and Assessment of Collateral Circulation

- Embolization is typically performed 24 to 48 hours prior to surgery for large tumors involving the jugular foramen and skull base. When the potential for sacrifice of major vessels exists, it is necessary to assess the cross-perfusion from the contralateral vessels. This is done using compression angiography, measurement of stump pressures, and temporary balloon occlusion. These studies are not 100% reliable, and more precise assessment is done using cerebral perfusion scans with single photon emission computer tomography (SPECT) imaging or xenon CT scan. Typically, patients who require sacrifice of an involved internal carotid artery and who perform well on these studies can be managed by preoperative permanent balloon occlusion. Those who fail the preoperative perfusion studies may require revascularization at the time of the resection.

Surgical Technique

General Considerations

- General anesthesia is preferred in all cases.
- With the exception of small glomus tympanicum tumors, an arterial line and central venous pressure line are inserted. Six units of blood are typed and cross-matched at the beginning of the procedure because of the risk of significant blood loss from these tumors.
- During the actual tumor dissection, particularly around the major vessels, the mean blood pressure is maintained at ~80 mm/Hg in younger patients and higher in older patients. The blood pressure is regulated pharmacologically with a continuous nitroglycerin infusion. This allows for rapid reversal of hypotension, if needed.
- Intraoperative facial nerve monitoring is routinely performed.
Transcanal Approach to Intratympanic Paragangliomas Limited to the Mesotympanum

- Complete tumor removal is possible through a transcanal approach. It is important to extend the tympanomeatal flap more inferiorly and anteriorly than in the usual fashion for stapes surgery so that the inferior aspect of the tympanic membrane can be fully elevated and the hypotympanum can be visualized and accessed.
- The artery that usually supplies these tumors is the tympanic branch of the ascending pharyngeal artery, and bipolar electrocautery is usually effective in securing hemostasis. Avoid unipolar electrocautery to prevent injury to the cochlea and the possibility of sensorineural hearing loss. Surgicel will be needed to occlude the bony canaliculus from which the vessel arises.
- If there is bleeding from the superior extent of the tumor, it is important to be careful not to disrupt the ossicular chain or traumatize the facial nerve while obtaining hemostasis using Surgicel®. In tumors that extend posteriorly and superiorly involving the ossicular chain, it is essential to identify the ossicular chain and separate the incudostapedial joint to avoid trauma to the inner ear. Once the tumor is removed, the ossicular chain can be reapproximated.

Mastoid Extended Facial Recess Approach to Tympanomastoid Tumors

- Patient preparation and draping are identical to that of routine tympanoplasty with mastoidectomy.
- An incision is made 1 to 2 cm behind the postauricular crease.
- A complete mastoidectomy is performed, and the facial recess is opened in the usual fashion using the chorda tympani nerve, vertical facial nerve, and fossa incudis as landmarks. The facial recess is extended by dividing the chorda tympani nerve and following the tympanic anulus into the hypotympanum.
- Bipolar electrocautery is used to control hemostasis and shrink the tumor. Cup forceps are used to remove the tumor from the hypotympanum in a fashion similar to that for the transcanal approach. Typically, bleeding of the vessel from the inferior part of the hypotympanum is controlled using Surgicel and Gelfoam, as well as bipolar electrocautery.
- Tumor extension to the lower part of the mastoid and retrofacial air cells is managed by performing a complete mastoidectomy. Tumor located inferior to the posterior semicircular canal, medial to the facial nerve, and superior to the jugular bulb can be removed. If extensive tumor involvement of the middle ear has already destroyed the ossicles and tympanic membrane, a tympanoplasty and ossicular chain reconstruction are performed using a fascial graft.

Mastoid Neck Approach to Small Jugulare Tumors Not Involving the Carotid Artery or Posterior Cranial Fossa

- An essential adjunct to this operation is intraoperative cranial nerve monitoring. In addition to monitoring the facial nerve, monitoring of cranial nerves IX, X, and XI is done.
This approach begins in the same fashion as the mastoid extended facial recess approach. Once the mastoidectomy is complete, the periosteum of the digastric ridge is exposed posteriorly toward the occiput and anteriorly toward the stylo-mastoid foramen. The mastoid tip is then amputated.

The postauricular incision is extended down the neck in a favorable neck crease, allowing exposure of the sternocleidomastoid muscle and ultimately identifying the great vessels in the neck, as well as the lower cranial nerves. The sternocleidomastoid muscle is detached from the mastoid tip. The posterior belly of the digastric muscle is dissected free and reflected anteriorly, allowing access to the great vessels and lower cranial nerves.

The jugular vein is identified in the upper neck, isolated, and ligated with multiple 0 silk sutures. The vein is freed from surrounding tissues and followed toward the jugular foramen. Be aware of the spinal accessory nerve that crosses the vein at this level. Staying on the vein will allow preservation of cranial nerves IX, X, and XI when they are not infiltrated by tumor.

In the mastoid, the sigmoid sinus and jugular bulb are completely exposed using a diamond bur. Bone over the proximal sigmoid sinus is kept intact to allow extraluminal packing of this sinus using Surgicel®. Once the sigmoid sinus has been packed proximally, the lumen of the sinus is opened distal to the packing. Brisk bleeding from the inferior petrosal sinus and the condylar vein will occur despite proximal control of the sigmoid sinus and distal control of the jugular vein. Surgicel is gently packed into the jugular bulb in an effort to occlude the inferior petrosal sinus and condylar vein while avoiding compression and subsequent injury to the lower cranial nerves on the medial aspect of the jugular foramen. Using a gimmick, and under direct microscopic control, the multiple openings for the inferior petrosal sinus are identified and packed.

Bipolar electrocautery is used to obtain hemostasis and shrink the tumor; the tumor is removed and dissected away from all the surrounding structures, including the carotid artery. The lateral portion of the jugular bulb is removed with the tumor, and residual bleeding is controlled using Surgicel.

Again, if total removal of the tumor requires removing the ossicular chain and the tympanic membrane, tympanoplasty and ossicular reconstruction can be performed.

These patients are managed in an intensive care setting for 24 hours to allow for early identification of lower cranial nerve neuropathy and postoperative hemorrhage.

The mastoid neck approach is too limited for the removal of tumors involving the petrous carotid artery.

Mastoid Neck Approach with Limited Facial Rerouting to Larger Tumors of the Jugular Foramen Not Involving the Carotid Artery or Posterior Cranial Fossa

For slightly larger tumors, more exposure is needed. Limited rerouting of the facial nerve from the second genu facilitates complete removal of the tumor with no added morbidity.
The vertical segment of the facial nerve is decompressed. The facial nerve is dissected free of its fibrous attachments within the fallopian canal from the second genu to the level of the stylomastoid foramen. The periosteum at the stylomastoid foramen is preserved such that, after mobilization of the posterior belly of the digastric muscle, the muscle and the soft tissues surrounding the stylomastoid foramen are reflected anteriorly as a whole, preserving the blood supply to the facial nerve in this region. This guarantees good facial nerve function after surgery. A suture is placed through the periosteum that allows anterior retraction of the nerve without tension.

This modified approach, again, allows for complete removal of the tumor from the retrofacial area inferior to the posterior semicircular canal.

Infratemporal Fossa Approach to Large Glomus Jugulare Tumors

The hallmark of this approach is the removal of the external auditory canal and complete rerouting of the facial nerve, allowing complete exposure of tumors involving the internal carotid artery. Tumor dissection is done with facial nerve monitoring and monitoring of the lower cranial nerves. There are eight distinct steps to the infratemporal fossa exposure:

1. **Patient preparation**  
   Wide exposure of the postauricular area and complete ipsilateral neck exposure. In the field, a large postauricular C-shaped incision is made and extended into the neck within a neck crease two fingerbreadths below the angle of the mandible.

2. **Management of the ear canal and tympanic ring**  
   The ear is dissected forward, and the ear canal is transected just medial to the bony-cartilaginous junction. The cartilage around the meatus is removed to facilitate eversion of the canal skin. The everted skin is closed using several interrupted 4–0 nylon sutures. This first layer of suture is buttressed by a second layer composing a musculoperiosteal flap that is pedicled posteriorly and sutured anteromedial to the ear canal.

3. **Mastoidectomy**  
   Complete mastoidectomy is done with an extended facial recess, allowing separation of the incudostapedial joint. The posterior exterior auditory canal is removed with its overlying skin. The remaining anterior canal skin and the tympanic membrane are also removed, as are the malleus and incus. The facial nerve is skeletonized from the geniculate ganglion to the stylomastoid foramen. *Avoid manipulation of the stapes and subsequent sensorineural hearing loss while removing the tympanic membrane and malleus and incus.* The bone of the tympanic ring is then removed superiorly, anteriorly, posteriorly, and inferiorly. Complete removal of the bone in this way allows identification of the jugular bulb, petrous carotid artery, and temporomandibular joint.

4. **Initial preparation of the jugular vein and neck exposure**  
   The postauricular incision is now carried into the neck, allowing for exposure of the sternocleidomastoid muscle. The mastoid tip is removed. The internal jugular vein, internal and external carotid arteries, and lower cranial nerves IX, X, XI, and XII are identified and preserved. Ligatures are placed around the internal carotid artery and the internal jugular vein for identification and vascular control. The posterior belly of the digastric muscle is dissected free from the digastric groove.
5. Transposition of the facial nerve  Transposition of the entire facial nerve to the geniculate ganglion is performed using a modification of the approach originally described by Fish. The posterior belly of the digastric muscle is dissected forward in continuity with the periosteum of the stylomastoid foramen. The facial nerve is freed within the facial canal from its fibrovascular attachments. A large silk suture is placed through the stylomastoid periosteum to secure it anteriorly to the soft tissue surrounding the zygomatic root. A large Perkins retractor is brought into the field and placed beneath the mandibular angle, and the entire mandible is retracted anteriorly. This maneuver obviates the need to resect the mandibular condyle even with large tumors that extend into the infratemporal fossa.

6. Completion of the neck exposure and identification of the lower cranial nerves and skull base carotid artery  The jugular vein and the external carotid artery are now doubly ligated proximally and distally in the neck. The proximal sigmoid sinus is doubly ligated with silk sutures if the tumor extends intradurally. If the tumor is extradural, the sigmoid sinus is packed extraluminally with Surgicel.

7. Tumor removal and intracranial extension  The jugular vein is then dissected from inferior to superior under the spinal accessory nerve to the level of the jugular bulb, and tumor is freed from the carotid artery. Bleeding from the carotid tympanic vessels is controlled with bipolar electrocautery. If the tumor intimately involves the carotid artery, a small portion of tumor is left attached to the carotid artery until the conclusion of the procedure. The tumor is dissected superiorly off the lower cranial nerves in continuity with the jugular bulb, and Surgicel is used to pack the inferior petrosal sinus and condylar vein. Extension of a small intracranial tumor is removed with the jugular bulb because this is typically the site of dural penetration. The decision to remove large tumors extending intracranially is based on the hemodynamic status of the patient. Removal of the intracranial portion is usually facilitated by the earlier steps of the procedure, which would have significantly devascularized the remnant. The remaining vessels can be cauterized discretely, and the tumor can be removed from the posterior fossa.

8. Full closure  Closure is accomplished by closing the eustachian tube with oxidized cellulose and a temporalis muscle plug. The dural defect is reaproximated as closely as possible, and thin strips of abdominal fat are used to plug any remaining dural defects and the lateral soft tissue defect. Large dural defects can be managed with a variety of local grafts and flaps, including temporalis fascia graft, temporoparietal fascia flaps, and temporalis muscle flaps. Regional and free flaps are reserved for large lateral skull base defects and previously irradiated fields. If cerebrospinal fluid leakage is encountered in the course of intracranial tumor dissection, continuous lumbar drainage is performed for approximately 5 days postoperatively.

Lateral Approach to Carotid Paragangliomas

◆ A lateral approach is used in most cases of carotid paragangliomas. A midline approach involving the splitting of the mandibular symphysis and hinging the jaw laterally is an alternative approach to lesions that extend to the skull base with no intracranial component. This latter approach will not be detailed in this chapter.
Maintenance of normal tension throughout the case is critical to avoid central neurological sequelae.

Patients are placed in the supine position with a sandbag under the ipsilateral shoulder to elevate it, and the head is turned to the contralateral side. The operating table is flexed to elevate the patient’s head and maintain good venous drainage.

A curvilinear skin incision begins at the mastoid process and follows the natural skin crease anteroinferiorly. If necessary, this incision can be extended preauricularly for mobilization of the parotid gland and the upper mandible as required. The incision is carried down through the platysma muscle along the anterior border of the sternocleidomastoid muscle.

An attempt is made to identify the great auricular nerve, mobilize it, and spare it if possible. The jugular vein is identified and mobilized. The common facial vein is ligated. The common carotid artery is identified and mobilized inferiorly. Vessel loops are placed around the common carotid artery for vascular control.

The dissection proceeds with mobilization of all the structures of the carotid triangle, including the hypoglossal nerve, spinal accessory nerve, and vagus nerve, as well as the internal carotid artery, external carotid artery, and its branches. Branches of the jugular vein and external carotid artery are ligated if necessary to expose the tumor. In some cases, the external carotid artery has to be ligated to control bleeding. Initially, the tumor is dissected away from its surroundings. Once this is done, the vagus nerve is identified at its entry into the tumor and carefully freed away from the tumor. The tumor is then dissected away from the underlying carotid artery. Combining sharp and blunt dissection helps removal of the tumor.

Once the tumor has been removed, hemostasis is obtained, the platysma layer is closed, and the wound is closed in layers, leaving a suction drain in the surgical site.

In all cases, an attempt should be made to preserve function of the vagus nerve, although this is not possible in the majority of cases. If the lesion is near the skull base, other cranial nerves such as the spinal accessory nerve and the glossopharyngeal nerves are at risk. Be prepared to do primary grafting of these nerves using the great auricular nerve. Postoperative management includes management of vagus nerve palsy, which produces hoarseness and dysphagia.

Reference

Temporal bone resection refers to a group of extirpative surgical procedures for resection of malignant disease affecting the external auditory canal (EAC) and temporal bone.

◆ **General Considerations**

◆ Unless the tumor is well isolated within the EAC, combined therapy with complete tumor removal and postoperative radiation is thought to provide the best locoregional tumor control.

◆ The issue of whether piecemeal resection compared with en bloc resection compromises survival rates is unclear.

◆ Gross tumor removal with microscopic disease-free margins will favor improved locoregional disease control. This is best achieved at the primary surgical resection.

◆ Tumor mapping for staging and surgical planning is best performed using high-resolution computed tomography (CT) imaging of the temporal bone. Magnetic resonance imaging (MRI) is useful in delineating intracranial and infratemporal fossa extension of tumor. Preoperative angiography and balloon occlusion testing with xenon/CT are indicated if resection of the involved internal carotid artery, with or without reconstruction, is being considered. The need for a metastatic workup is determined by tumor pathology and the likelihood of locoregional and systemic spread of disease.

◆ A preoperative audiogram should be obtained to define hearing in both ears even though the extent of surgery is defined by the extent of tumor rather than residual hearing function.
The need for neurosurgical and/or plastic reconstructive expertise should be anticipated preoperatively.

### Defining the Extent of Surgery

Three broad categories of temporal bone resection have been defined:

- **Lateral**  Indicated for malignancies limited to the EAC without tympanic membrane violation. If tumor is limited to the lateral EAC, a resection of the EAC sleeve, lateral to the tympanic membrane, may be performed.
- **Subtotal**  Indicated for tumors involving the middle ear and mastoid cavity. The medial extent of resection incorporates the otic capsule and is dictated by the areas of tumor infiltration.
- **Total**  Indicated for tumors eroding the cochlea, petrous apex, and carotid canal.

The limits of each of these procedures are illustrated in **Fig. 32–1**.

### Surgical Technique

General anesthesia is administered with short-acting muscle relaxants during the initial induction to allow for intraoperative monitoring of cranial nerve function.

**Figure 32–1** Anatomical limits of temporal bone resection subtypes. (1) Lateral temporal bone resection. (2) Subtotal temporal bone resection. (3) Total temporal bone resection.
The facial nerve is routinely monitored. Additional monitoring of cranial nerves IX, X, and XI is done if these nerves need to be identified and preserved at the time of surgery. With intracranial involvement, cerebral and brainstem traction or injury may be monitored using somatosensory evoked potentials and contralateral auditory brainstem response recordings.

Consideration should be given to the need for reconstructive options at the time of preparing and draping the patient.

Perioperative broad-spectrum antibiotics with good cerebrospinal fluid (CSF) penetration, such as third-generation cephalosporins, are administered at induction. Furosemide (Lasix) 10 mg and mannitol 0.5 g/kg are administered 30 minutes prior to the intracranial portion of the procedure to decompress the subarachnoid space if retraction of the temporal lobe or cerebellum is anticipated.

Lateral Temporal Bone Resection

The EAC is removed en bloc, along with the tympanic membrane, malleus, and incus.

Boundaries of resection include the middle ear medially, the temporomandibular joint (TMJ) capsule anteriorly, the zygomatic root superiorly, the mastoid cavity posteriorly, and the infratemporal fossa (ITF) inferiorly. Laterally, the pinna may be partially or completely removed, depending on local tumor involvement. Unless the pinna is substantially involved with disease, leaving some pinna at the root of the helix will provide support for wearing eyeglasses postoperatively.

The ear canal is injected with 1% lidocaine with 1:100,000 epinephrine.

For tumors limited to the EAC without tragal involvement, a circumferential incision is made around the concha, leaving the tragus intact. A large postauricular C-shaped incision is then made up into the temporal area and down into the upper neck, with further inferior extension if a neck dissection is planned.

An anteriorly based skin flap is then created by dissecting just lateral to the fibroperiosteal layer over the mastoid cortex, until the posterior part of the conchal incision is reached, then connected circumferentially with the postauricular wound. The lateral EAC skin is everted off the cartilage and oversewn after confirmation of negative lateral tumor margins. The skin flap is then raised further anteriorly over the parotid fascia superiorly and the sternocleidomastoid (SCM) fascia inferiorly to provide exposure for the parotid gland and neck.

A complete mastoidectomy is performed, exposing the digastric ridge inferiorly and the tegmen tympani anterosuperiorly in the epitympanum, then continuing anteroinferiorly around the bony canal until the glenoid fossa is reached and the TMJ capsule identified. This leaves the EAC attached anteromedially only by the bone immediately lateral to the eustachian tube. Avoid violating the bony external auditory canal.

The facial recess is opened, and the vertical facial nerve is skeletonized. This is extended inferiorly and anteriorly through the tympanic bone medial to the annulus.

After separating the incudostapedial joint through the facial recess, the remaining anterior bony attachment of the EAC is transected using a small osteotome, taking care to avoid injury to the internal carotid artery medial to the eustachian tube. The anterior bony canal is then dissected off the TMJ capsule.
If indicated by tumor extension, a superficial parotidectomy is performed by following the facial nerve down to the stylomastoid foramen and anteriorly into the parotid bed. If facial nerve preservation is possible, the cuff of fibrous tissue encasing the nerve at the stylomastoid foramen is left to minimize postoperative facial paresis/paralysis. The EAC and parotid specimens are then removed in continuity.

Subtotal Resection of the Temporal Bone

- In individuals with any tumor violation of the tympanic membrane, a subtotal temporal bone resection is recommended.
- Whereas the EAC may be removed en bloc as described above, the middle ear structures are generally removed piecemeal without any significant negative impact on locoregional control or overall survival. The strategy is to perform a large extradural subperiosteal resection of the temporal bone, leaving the dura over the middle fossa superiorly, dura over the posterior fossa and sigmoid sinus posteriorly, internal carotid artery anteriorly, jugular bulb inferiorly, and petrous apex medially.
- The facial nerve is skeletonized along most of its intratemporal course. If the facial nerve is uninvolved and preservation is attempted, a translabyrinthine dissection (see Chapter 30) is completed to expose the facial nerve in the internal auditory canal (IAC), and the greater superficial petrosal nerve is transected at the geniculate ganglion. This allows posterior transposition of the nerve and piecemeal tumor resection anteromedially in the temporal bone. If the facial nerve is to be sacrificed, the IAC is still opened, and the facial and cochleovestibular nerves are transected.
- Bone of the otic capsule is carefully removed piecemeal by using a diamond burr to isolate the vertical carotid artery and jugulocarotid spine. This leaves bone of the petrous apex medially.

Tumors Involving the Jugular Foramen

- Lateral wall of sigmoid and jugular bulb involved only: Tumor resection is accomplished using a Fisch type A infratemporal fossa approach (see Chapter 33). The internal jugular vein (IJV) and cranial nerves IX, X, XI, and XII are identified and isolated in the neck. The IJV is doubly ligated using 2–0 silk and divided. Superiorly, the sigmoid sinus may be extraluminally packed with Surgicel or ligated just below the takeoff of the superior petrosal sinus by incising the dura anterior and posterior to the sigmoid and passing a 2–0 silk tie around the sinus using a curved clamp. If packing the sigmoid, be careful not to pack too far posteriorly to avoid occluding the vein of Labbé and transverse sinus, which may lead to temporal lobe infarction. The tumor is removed along with the lateral wall of the jugular bulb. Bleeding from the medial wall of the bulb through the inferior petrosal sinus is controlled with surgical packing.
- Medial wall of jugular bulb involved: Contents of the pars nervosa, including cranial nerves IX, X, and XI, are excised along with tumor. Nerve margins are checked
for residual tumor involvement. If intracranial nerve resection is necessary, a retrosigmoid approach is used (see Chapter 30). Resultant dural defects may be repaired with fascia or pericranium. Consideration is then given to the need for immediate or postoperative rehabilitation of these lower cranial nerve deficits.

**Tumors Involving the Dura**

- Resection of the involved dura is performed with neurosurgical support, and reconstruction of the dural defect is accomplished using temporalis fascia, pericranium, or homograft tissue.
- Tumor extension into brain parenchyma portends a poor overall prognosis even if gross tumor removal is accomplished intracranially.

**Tumors Involving the Infratemporal Fossa**

- This will necessitate further anterior exposure. The skin flap is extended anterosuperiorly and elevated over the deep temporal fascia until the region of the frontal branch of the facial nerve. At this point, further dissection is continued deep to the superficial temporal fat pad to avoid injury to the frontal branch. The anterior limit of exposure is the orbit and zygomatic arch.
- Using Bovie electrocautery, the periosteum over the lateral orbital rim and superior edge of the zygomatic arch is incised. Soft tissue lateral, medial, and inferior to the zygomatic arch is dissected in a subperiosteal plane.
- V-shaped osteotomies are then made in the zygomatic arch to allow for its removal. This allows access for dissection of the underlying temporalis muscle off the cranium and anteroinferior reflection of the muscle, pedicled on the coronoid process of the mandible.
- A total parotidectomy is performed, with or without preservation of the facial nerve as determined by tumor involvement. The mandibular condyle is then resected down to the level of the coronoid notch, along with soft tissues around it. This may necessitate sacrifice of the frontal branch of the facial nerve for access to the mandible.
- Subperiosteal tumor dissection along the skull base is continued as described in Chapter 33, preserving neurovascular structures in this area not involved with tumor.
- A temporal craniotomy is performed to remove the floor of the middle fossa. Elevation of the middle fossa dura prior to bony resection is defined by the IAC posteriorly, the superior petrosal sinus medially, and the foramen ovale with V3 anteriorly.

**Total Resection of the Temporal Bone**

- This represents an extensive resection of the petrous temporal bone with further risk to the surrounding critical neurovascular structures.
- After completing a subtotal temporal bone resection, vascular control of the petrous carotid artery is obtained by proximally isolating the vertical carotid at the
The resultant cavity is similar to that after a radical mastoidectomy. If the defect is deep, it may be partially obliterated with a pedicled temporalis muscle flap or pedicled myocutaneous flaps. Small radical mastoidectomy-like defects may be covered with split-thickness skin grafts. If postoperative radiation is planned, the skin graft should be laid over a pedicled temporalis muscle flap using the posterior half of the temporalis muscle to provide vascular support for the graft.

- The eustachian tube is obliterated using a combination of muscle, fascia, bone, and/or Surgicel.

Subtotal and Total Temporal Bone Resection

- These resections leave large surgical defects with the potential for CSF leakage. The goal of reconstruction in these cases is therefore twofold: cosmetic and prevention of CSF leakage.
- Due to the size of the defect, this usually necessitates a vascularized regional or free flap, with or without a split-thickness skin graft over it, depending on the type of flap used.
- Drains are left in the lower neck only. Suction should be applied to the drains only if a watertight closure has been achieved medially and the risk of CSF leakage is negligible.
- Layered closure using absorbable sutures in the deep layers and nonabsorbable sutures in the skin layer should be performed.

Facial Nerve Reconstruction

- If proximal and distal ends are available for grafting, the facial nerve may be reconstituted using a greater auricular or sural cable nerve graft (see Chapter 28).
- If the proximal extent of nerve resection is at the brainstem, a hypoglossal-facial nerve anastomosis is preferred (see Chapter 29).
Postoperative Management

- The patient’s head should remain elevated and stool softeners should be administered during the postoperative period to reduce the risk of CSF leak.
- The mastoid dressing or head wrap is removed on postoperative day 1 for resections without risk of CSF leakage, and at day 4 for the remaining patients.
- The patient should be monitored for CSF leakage through the drains, wound, and/or nose. If this is discovered early, a lumbar drain may be placed to control the leakage. Lumbar drains are not routinely placed at the time of surgery unless extensive dural resection is necessary at the time of surgery. CSF leakage from the wound will necessitate suture reinforcement under sterile conditions, with reapplication of a pressure dressing for 3 to 4 days. Persistent CSF leakage will require surgical wound reexploration.
- Any venous congestion in the remaining pinna may be treated using medical-grade leeches.
- Early mobilization of the mandible in patients who have had condylar resections minimizes postoperative trismus.
- Routine eye care is provided for patients with postoperative facial palsy.
- A tracheotomy and feeding tube may be necessary for those with lower cranial nerve palsy resulting from surgery. Consult a speech pathologist early.
- Postoperative radiation is administered 6 weeks after surgery to allow for adequate wound healing.
33

Infratemporal Fossa and Petrous Apex Approaches

Elizabeth H. Toh

◆ Infratemporal Fossa Approaches

◆ Infratemporal fossa (ITF) approaches are used to access tumors of the temporal bone extending inferiorly to or beyond the jugular foramen, tumors of the jugular foramen, tumors involving the petrous carotid artery, and tumors involving the deep lobe of the parotid gland with temporal bone involvement.

◆ Surgical access to the ITF may be obtained using a postauricular incision for primary temporal bone and jugular foramen lesions; a preauricular incision is used to access more anteriorly based lesions, which do not involve the petrous temporal bone.

◆ Preservation of neurovascular structures within and in the vicinity of the ITF remains the limiting factor in developing and modifying these surgical approaches.

Preoperative Considerations

◆ Computed tomography (CT) and magnetic resonance imaging (MRI) provide complementary anatomical information necessary for preoperative planning.

◆ MR angiography is useful in assessing tumor involvement of the petrous carotid artery. If tumor resection necessitates resection of the contiguously involved petrous carotid artery, preoperative angiography and balloon occlusion with xenon/CT imaging is required to assess the adequacy of collateral cerebral blood flow.

◆ Preoperative embolization is performed 24 to 48 hours prior to surgery for juvenile angiofibromas and paragangliomas.
Reconstructive and rehabilitative options should be thoroughly assessed prior to surgery, and a multidisciplinary approach should be used to ensure optimal functional and cosmetic outcomes.

Surgical Technique

- This section describes the most commonly employed Fisch-type ITF approaches, which permit access to the ITF mostly through the temporal bone, with or without facial nerve rerouting.
- General anesthesia is employed without the use of muscle relaxants after induction. This is necessary because intraoperative neurophysiologic monitoring is routinely employed. The specific cranial nerves monitored will depend on the nerves likely to be involved by or adjacent to the tumor and surgical dissection site.
- The patient is positioned supine, with the head turned to the contralateral side.
- Preparation and draping should take into account the potential donor sites needed for reconstructive surgery.

Fisch Type A Approach

- This is described in detail in Chapter 31. This approach is used most commonly for removal of glomus jugulare tumors.
- The original description of this procedure describes anterior rerouting of the facial nerve. In selected cases with smaller tumors, the facial nerve may be skeletonized and left in situ within the fallopian canal. Tumor dissection is performed lateral and medial to the nerve. This theoretically reduces the risk of postoperative facial weakness, which almost always occurs with rerouting the nerve.

Fisch Type B Approach

- This approach provides more anterior access to the petrous apex and clivus by displacing the zygomatic arch and temporalis muscle inferiorly and removing bone of the middle fossa floor.
- A large C-shaped postauricular incision is made behind the ear. Transection and blind sac closure of the external auditory canal are performed.
- The course of the facial nerve in the mastoid is identified and exposed down to the stylomastoid foramen. The nerve is not rerouted.
- Periosteum over the zygomatic arch is incised and reflected inferiorly to protect the frontal branch of the facial nerve. Osteotomies are then performed anteriorly close to the orbital rim, and posteriorly close to the zygomatic root. The zygomatic arch is then retracted inferiorly with its attached masseter muscle. The temporalis muscle is elevated off the cranium and reflected inferiorly.
- A subtotal petrosectomy is performed by completing a cortical mastoidectomy, decompressing bone over the sigmoid sinus and posterior and middle fossa dura, and removing the posterior wall of the external auditory canal. The skin of the ear canal is removed, along with the tympanic membrane, malleus, and incus. The otic capsule is preserved, as is the facial nerve within the fallopian canal. Drilling is then continued anteriorly along the petrous carotid artery.
The temporomandibular joint is disarticulated, and bony dissection of the zygomatic root and glenoid fossa is completed. This provides access to the floor of the middle fossa where the neurovascular structures traversing the various foramina are encountered. The middle meningeal artery may be ligated at foramen spinosum and V3 transected at foramen ovale for added medial exposure.

The carotid artery is completely skeletonized if mobilization is necessary to access the petrous apex and clivus. The eustachian tube lies lateral and parallel to the carotid artery in this location and should be plugged.

The large bony defect resulting from this approach must be closed with a substantial soft tissue graft or pedicled temporalis muscle. The zygomatic arch is replaced and secured with microplates. The soft tissues and skin are then reapproximated in layers.

**Fisch Type C Approach**

- The Fisch type C approach represents an extension of the type B approach and provides even further access anteriorly to the anterior ITF, sella, and nasopharynx.
- Surgical dissection proceeds as described for the type B approach. Medially, the soft tissues overlying the pterygoid plates and pterygoid fossa are dissected free. The pterygoid plates are drilled away to enable access to the posterolateral nasopharynx, posterior maxillary sinus, palate, and cavernous sinus.
- This approach will result in a large bony and soft tissue defect, which is most appropriately reconstructed using a vascularized flap. Care must be taken to meticulously seal off the nasopharynx and oropharynx, so as to minimize the risk of wound contamination postoperatively.

**Fisch Type D Approach**

- The Fisch type D approach uses a preauricular incision, orbitozygotomy, and middle fossa floor resection to provide anteromedial dural exposure, similar to the type C dissection.
- Because a preauricular incision is made, the surgical approach is anterior to the ear. As such, the hearing conduction mechanism is not violated, and the facial nerve does not require rerouting. This is the primary distinguishing feature of the type D approach.
- The type D approach enables surgical access as far forward as the pterygopalatine fossa and lateral orbital wall.

**Petrous Apex Approaches**

- Surgical access to the petrous apex may be obtained through the temporal bone laterally, or anteriorly through the nose. The critical anatomical structures limiting access to the petrous apex include the otic capsule, the carotid artery, and the facial nerve.
Factors influencing selection of approach used include hearing status in the affected ear, location of the lesion relative to surrounding neurovascular structures, and nature of the lesion.

Hearing preservation approaches include the transsphenoidal approach, transcanal infracochlear approach, transmastoid infralabyrinthine approach, and middle fossa approach.

In the nonhearing ear, a translabyrinthine approach may be used. If additional access is desired, the cochlea may be sacrificed.

Definitive surgical management of lesions within the petrous apex include surgical excision, drainage, and exteriorization. Drainage and ventilation are adequate for cholesterol granulomas. Epidermoids ideally should be completely removed. In the hearing ear, exteriorization may be preferred to preserve cochlear function.

Preoperative Considerations

CT and MRI provide complementary information necessary to determine the nature of the lesion involved. In addition, bony details on CT imaging provide anatomical information necessary for selecting the most appropriate surgical approach.

A preoperative audiogram should be obtained to assess hearing in the affected ear.

Surgical Technique

Surgery is performed under general anesthesia in all cases. Muscle relaxants should be avoided if intraoperative facial nerve monitoring is being employed for any of the transtemporal approaches.

Transcanal Infracochlear Approach

This approach is ideal for drainage of cholesterol granulomas where adequate bony access between the cochlea and carotid artery is confirmed on coronal CT imaging of the temporal bone.

Theoretically, any long-term problems with the ventilating port may be managed through a large myringotomy.

The ear canal and postauricular areas are injected with 1% lidocaine with 1:100,000 epinephrine. Standard vascular strip incisions are made through the canal prior to incising the postauricular soft tissues.

Once the ear canal is exposed through the postauricular approach, a superiorly based tympanomeatal flap, pedicled on the umbo of the malleus, is elevated to access the middle ear.

The bony ear canal is enlarged inferiorly using diamond burs to expose the hypotympanum. Drilling of the posterior canal wall should be limited by the chorda tympani nerve, because the vertical facial nerve may be encountered in this direction. The goal of this step is to provide adequate visualization of the jugular bulb and carotid artery.
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◆ Using a small diamond burr, the triangle of bone bounded anteriorly by the carotid artery, posteriorly by the jugular bulb, and superiorly by the cochlea is drilled anteromedially toward the nose. Drilling should err anteriorly adjacent to the carotid artery, which possesses a harder wall compared with the jugular bulb.

◆ When the cyst wall is encountered, a thick brownish fluid will drain. The fluid content of the cyst is evacuated and the bony tunnel is stented using a pediatric feeding tube or rolled Silastic sheeting (Fig. 33–1). The lateral extent of the stent should extend beyond the middle ear mucosa to minimize the risk of postoperative stent occlusion.

◆ The inferior bony ear canal is reconstructed using bone pate prior to replacement of the tympanomeatal flap. Any residual defect between the flap and ear canal should be grafted using a standard underlay technique with temporalis fascia.

◆ The vascular strip is replaced along the posterior canal wall, and the ear canal is packed with antibiotic-soaked Gelfoam pledgets. The postauricular wound is closed in layers.

Transmastoid Infralabyrinthine Approach

◆ A high-riding jugular bulb is a contraindication for using this approach.

◆ A standard postauricular approach for mastoid surgery is used. No ear canal incisions are made.

Figure 33–1 Placement of stent for postoperative ventilation using the transcanal infracochlear approach. CA, carotid artery. JB, jugular bulb; P, promontory.
A complete mastoidectomy is performed. The antrum is exposed and the facial recess opened after identification of the lateral semicircular canal and incus body. The vertical facial nerve is skeletonized down to the stylomastoid foramen.

The sigmoid sinus is decompressed and bony removal is continued posterior to the sigmoid to allow further sigmoid decompression. This provides a better angle for access to the petrous apex.

The posterior semicircular canal is then identified, and bone posterior and medial to the vertical facial nerve, between the ampulla of the posterior semicircular canal superiorly and the jugular bulb inferiorly, is drilled in an anteromedial direction. Drilling is continued until the cyst wall is encountered.

The cyst wall is incised, the contents of the cyst drained, and exposed cyst wall removed piecemeal to maximize petrous apex ventilation postoperatively. The cavity is irrigated with antibiotic solution and permanent ventilation is afforded using a rolled Silastic sheeting placed inferiorly in the mastoid cavity (Fig. 33–2).

The postauricular incision is then closed in layers.

Figure 33–2 Placement of stent after transmastoid infracochlear drainage of petrous apex cholesterol granuloma. FN, facial nerve; JB, jugular bulb; LSC, lateral semicircular canal; PSC, posterior semicircular canal.
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Translabyrinthine Approach

◆ The details of this approach are described in Chapter 30.
◆ The internal auditory canal (IAC) is skeletonized, taking care to preserve the dura of the IAC. The epitympanum is exposed and the facial recess opened.
◆ Bony dissection is then continued above and below the IAC. Care is taken to avoid injuring the facial nerve in its course along the lateral IAC when drilling above the IAC. Bony dissection under the IAC is limited inferiorly by the jugular bulb.
◆ Once the cyst wall is identified and incised, the cyst contents are drained and the surgical wound thoroughly irrigated with antibiotic solution. Stenting is not required using this approach.
◆ The postauricular wound is closed in layers.

Middle Fossa Approach

◆ This approach affords access to the petrous apex from above while preserving hearing. The inability to ventilate the petrous apex through this approach limits its utility in surgical management of cholesterol granulomas.
◆ The details of this approach are described in Chapter 30.

Transsphenoidal Approach

◆ This approach provides anterior access to the petrous apex lesion without any significant risk of injury to the cochlea and facial nerve.
◆ The use of image guidance further reduces the risk of injury to surrounding neurovascular structures while providing real-time mapping of the lesion during surgery.
◆ Details of the transsphenoidal approach are discussed in Chapter 5.
◆ The disadvantage of this approach is the inability to reliably ventilate the petrous apex long term.
The maxilla articulates with the bones of the skull base, and therefore maxillary surgery is occasionally performed to provide exposure for treatment of skull base pathology. This chapter, however, will focus on surgery for pathology that involves the maxilla primarily.

Squamous cell carcinoma and salivary tumors are generally responsible for the majority of cases requiring extirpative maxillary surgery.

**Preoperative Considerations**

Evaluation of a tumor involving the maxilla must include a biopsy of the lesion for histologic analysis and appropriate radiologic imaging to delineate the exact location and extent of the lesion.

For tumors involving the intraoral or external surfaces of the maxilla, the biopsy is usually straightforward. However, care should be taken to provide viable cells for analysis as well as to avoid any procedure that might compromise future therapeutic interventions. If a vascular lesion is suspected, the biopsy should be delayed until all imaging has been obtained to avoid excessive bleeding, which may compromise radiologic evaluation. Lesions not directly visible can often be accessed with a rigid nasal telescope or an examination under anesthesia with endoscopic or Caldwell-Luc antrostomy to provide tissue for diagnosis. Image guidance systems can provide assistance for the biopsy. Associated neck masses should be evaluated with fine-needle aspiration biopsy.

The choice of imaging modality should be guided by the differential diagnosis. In general, evaluation of bony involvement is best accomplished with computed tomography (CT), and the extent of soft tissue involvement is better delineated by magnetic resonance imaging (MRI). For complete radiologic evaluation of complex
lesions, CT and MRI should be included in the assessment. The radiologic appearance of the tumor often assists in the differential diagnosis. For odontogenic lesions, dental imaging (either plain films or CT dentascan) can provide valuable information. CT and MR angiography have largely replaced conventional angiography as a diagnostic entity for those cases requiring endovascular therapy.

◆ An appropriate metastatic workup should be undertaken in patients who have been diagnosed with a malignant tumor. In general, this should include imaging of the regional lymphatics and chest. A diagnosis of secondary malignancy should initiate a search for the primary lesion.

◆ Surgical Technique

Incisions

◆ Several incisions have been used to facilitate the variety of surgical procedures encompassed by the term maxillectomy. The different types of incisions are based on three fundamental but competing principles of exposure, function, and cosmetic outcome. The incisions used for a maxillectomy can be simplified by dividing them into external and internal incisions (Table 34–1).

Table 34–1 Incisions Used in Ablative Maxillary Surgery

<table>
<thead>
<tr>
<th>Incision</th>
<th>Exposure</th>
<th>Functional Concerns</th>
<th>Cosmesis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>External</strong></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
| Lateral rhinotomy (LR) | Intranasal neoplasm<br>Medial maxillectomy | Alar collapse | ++++
| LR with Lynch extension | Medial maxillectomy and ethmoidectomy<br>Medial and posterior maxillectomy | Medial epicanthal ligament misplaced<br>Nasolacrimal duct obstruction | ++
| LR with Lynch extension and bicoronal incision | Craniofacial resection for skull base neoplasms<br>Medial maxillectomy | As above<br>Resection related (anosmia) | +++
| Weber-Ferguson (WF) | | Upper lip contracture | ++
| WF with subciliary extension | Subtotal and total maxillectomy | Lower eyelid edema<br>Ectropion<br>Infraorbital nerve injury | +
| WF with supraciliary and subciliary extension | Total maxillectomy with orbital exenteration<br>Maxillectomy combined with overlying skin resection | Resection related (orbital resection)<br>Resection related (facial nerve, infraorbital nerve) | —
| Transfacial | | | |

(Continued)
Figure 34–1 Lateral rhinotomy.

Table 34–1 Incisions Used in Ablative Maxillary Surgery—(Continued)

<table>
<thead>
<tr>
<th>Incision</th>
<th>Exposure</th>
<th>Functional Concerns</th>
<th>Cosmesis³</th>
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<tbody>
<tr>
<td>Internal</td>
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<td></td>
<td></td>
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<tr>
<td>Peroral</td>
<td>Alveolectomy</td>
<td>Resection (speech, mastication)</td>
<td>++++</td>
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<td></td>
<td>Palatectomy</td>
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<td></td>
<td>Infrastructure maxillectomy</td>
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<tr>
<td></td>
<td>Midface degloving</td>
<td>Vestibular stenosis</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Infrastructure maxillectomy</td>
<td>Infraorbital nerve injury</td>
<td></td>
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<tr>
<td></td>
<td>Medial maxillectomy</td>
<td>Exposure of the contralateral (healthy) midface</td>
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<tr>
<td></td>
<td>Subtotal and total maxillectomy</td>
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<td></td>
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<tr>
<td>Endoscopic</td>
<td>Intranasal neoplasm</td>
<td>Advanced endoscopic skills required</td>
<td>++++</td>
</tr>
<tr>
<td></td>
<td>Medial maxillectomy</td>
<td>Difficulty with en bloc resection</td>
<td></td>
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</tbody>
</table>

² + signs indicate degree of cosmesis, with ++ indicating acceptable cosmesis and ++++ indicating excellent cosmesis.
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◆ The lateral rhinotomy utilizes the anatomical nasal subunits to provide excellent cosmetic and functional results. The incision (Fig. 34–1) begins midway between the medial canthus and dorsum of the nose, follows the lateral aspect of the side wall inferiorly, and continues around the alar rim, ending within the nostril.

◆ Although the lateral rhinotomy approach provides adequate exposure for limited resections, more comprehensive maxillectomies require greater exposure. This can be accomplished three ways:
  1. Extending the incision inferiorly through the lip along the philtrum to allow elevation of a cheek flap, creating the Weber-Ferguson incision (Fig. 34–2)
  2. Extending the incision superiorly to the medial end of the eyebrow (Lynch extension) (Fig. 34–3), with elevation of the medial canthal ligament and division of the nasolacrimal duct
  3. Extending the incision laterally below the lower eyelid, above the upper lid, or both (Fig. 34–4)

These extensions can be combined, and almost all types of maxillectomy can be performed via this approach and its variations.

Internal Incisions

◆ The majority of limited infrastructure maxillectomies can be performed via a perioral route without using an external incision. The placement of the intraoral

Figure 34–2 Lateral rhinotomy with Lynch extension. A small W-plasty is incorporated at the medial canthal level to minimize webbing.
Figure 34–3 Weber-Ferguson incision. The arrow demonstrates lip-splitting incision.

Figure 34–4 Weber-Ferguson incision with supra- and subciliary incisions.
incision is determined by the extent of the tumor resection, but it requires adequate labial and cheek retraction for exposure and appropriate osteotomies for en bloc tumor extirpation.

The midface degloving approach described by Casson et al. has been applied to almost all forms of maxillectomy. This approach involves extended sublabial and gingivobuccal incisions, a septal transfixion incision, an intercartilaginous incision, and a pyriform aperture incision. It allows the soft tissue of the midface to be separated from the maxillae and therefore provides excellent bilateral maxillary exposure. The major advantage of this approach is that it avoids a facial incision; however, it is technically more demanding than the transfacial approaches. Vestibular stenosis may result from the circumferential vestibular incision and may result in a significant functional complication.

**Maxillectomy**

There is no uniform approach to maxillary surgery for resection of benign or malignant tumors. The extent of surgery and thus the approach are determined by each patient’s particular pathology. In general, a limited maxillectomy involves resection of one wall; a subtotal maxillectomy has two walls resected, and a total maxillectomy has all walls of the maxilla resected.

**Limited Maxillectomy**

There are three types of limited maxillectomy: medial maxillectomy, infrastructure maxillectomy or alveolectomy, and anterolateral maxillectomy (Fig. 34–5).

![Figure 34–5](image-url) Limited maxillectomy. (A) Medial maxillectomy. (B) Infrastructure maxillectomy. (C) Anterolateral maxillectomy.
Medial Maxillectomy

This is classically used for the management of lesions of the lateral nasal wall, most commonly inverting papilloma. Although classified under maxillectomy, the medial maxillectomy commonly involves resection of not only the medial wall of the maxilla, but also the inferior turbinate and portions of the ethmoid and, sometimes, the lacrimal bones.

The goal is removal of the lateral nasal wall from the floor to the ethmoid roof and from the pyramidal aperture to the plane defined by the most posterior aspect of the maxilla.

Though often performed through a lateral rhinotomy approach, a midface degloving approach may also be employed to increase surgical exposure.

Transnasal endoscopic medial maxillectomy has been described, and as expertise with endoscopic surgery progresses, this approach is becoming more common. The principal drawback of endoscopic maxillectomy is failure to provide an en bloc tumor specimen. This, however, does not seem to have a significant effect on outcome in appropriately selected patients.

Infrastructure Maxillectomy/Alveolectomy

This is used commonly for diseases originating in the oral cavity or those of odontogenic origin.

The procedure is designed to resect the involved alveolar segment and/or hard palate. Resection can encompass as little as a segment of hard palate to varying degrees of alveolectomy, to total bilateral alveolectomy and palatectomy.

Smaller lesions generally are approached transorally via a sublabial incision, and more extensive pathologies generally require either an extended lateral rhinotomy or a midface degloving approach.

Anterolateral Maxillectomy

This is the least common of the limited maxillectomies.

It is most commonly used to manage pathology arising from the facial skin, the parotid gland, or the bucco-alveolar sulcus that involves the maxilla secondarily.

Surgical access to the anterolateral maxilla is generally accomplished through facial incisions designed to manage the primary location of the tumor. Excellent exposure can also be accomplished through either an extended lateral rhinotomy approach with a lip split or a midface degloving approach.

Subtotal Maxillectomy

This involves complete resection of the maxilla except for the roof of the maxillary sinus (Fig. 34–6).

It is generally used for neoplasms arising in the maxillary sinus sparing the bone of the orbital floor or for more extensive pathology of the oral cavity.

Midface degloving or extended lateral rhinotomy approaches are used and provide excellent exposure.
Total Maxillectomy with Orbital Preservation

- When the tumor involves the bony orbital floor, a total maxillectomy is required to provide complete tumor resection (Fig. 34–6).
- Most surgeons agree that orbit sparing is ideally suited for those patients whose periorbita has not been invaded by tumor. With the increasing use of adjuvant cancer therapies and the realization that aggressive orbital exenteration seldom results in a significant survival advantage, a more conservative approach utilizing orbit-sparing maxillectomy is usually recommended.
- A midface or an extended lateral rhinotomy approach is used for orbit-sparing total maxillectomy.

Total Maxillectomy with Orbital Exenteration

- With obvious maxillary tumor invasion extending into the orbit, a total maxillectomy with orbital exenteration is warranted (Fig. 34–6). Because these tumors often require extensive resection and adjuvant cancer treatment, there is a low probability of regaining adequate eye function. Therefore, orbital exenteration is recommended.
- Orbital exenteration is generally subdivided into two groups: preservation of the eyelid and resection of the eyelid.
A lateral rhinotomy is commonly used with a supraorbital extension, upper and lower lid incisions, or transconjunctival incisions, depending on the intention to spare or sacrifice the eyelids.

**Intraoperative Considerations**

- Prophylactic antibiotics are used to minimize the risk of septic complications.
- The method of airway control during a maxillectomy depends on the planned surgical approach and the anticipated extent of resection and reconstruction. Most patients do not require a tracheostomy for an uncomplicated maxillectomy and the surgery can be safely performed with orotracheal or nasotracheal intubation.
- Tarsorrhaphy sutures are routinely used to prevent corneal abrasion during surgery.
- When a Lynch extension is used, the medial epicanthal ligament and nasolacrimal duct are divided. The medial epicanthal ligament requires reapproximation to the bone to prevent displacement of the globe and hypertelorism. Early postoperative epiphora is common and should subside if the nasolacrimal duct has been positioned appropriately into the nasal cavity. A dacrocystorhinotomy is routinely performed during those cases where the nasolacrimal duct is transected. A lacrimal stent is generally placed and left in situ for 6 weeks as the tract heals.

**Reconstruction**

- Reconstruction of midface defects, which include those defects created by a maxillectomy, represents one of the greatest challenges facing the reconstructive head and neck surgeon. Although a comprehensive discussion of this topic is outside the scope of this chapter, a brief overview of modern reconstruction options and the general principles used in choosing a reconstructive method will be presented.
- Reconstructive options are summarized in Table 34–2.
- The goals of reconstruction following maxillectomy include separation of the oral and nasal cavities, support of the orbital contents, adequate projection of the midface, and restoration of surfaces for mastication.
- For more extensive ablative procedures, the reconstructive surgeon is also occasionally faced with exposure of intracranial contents, which must be separated from any contaminated spaces with a watertight seal.
- For limited resections such as a medial maxillectomy, the cosmetic and functional deficits created are minimal, and therefore no true reconstructive effort is required. Small resections involving the alveolus, hard palate, or anterolateral surface of the maxilla can be closed with local tissue flaps such as the palatal island flap or the facial artery myomucosal (FAMM) flap.
- For more extensive alveolar resections, an obturator or a fasciocutaneous free flap combined with a dental prosthesis can achieve an excellent functional and cosmetic outcome. Although obturation generally is well tolerated, some patients experience difficulty in inserting the prosthesis and/or nasal reflux due to leakage.
around the obturator. The decision of which reconstruction to use is based on numerous factors, including the age and general medical status of the patient, the prognosis of the disease, the status of the remaining teeth, and patient needs. Adequate manual dexterity is required for insertion of the obturator. Younger patients with good dentition often benefit from free flap separation of the oral and sino-nasal cavities because this permits oral intake with no nasal regurgitation without wearing the dental appliance. The needs of the patient must always be balanced with the risks of free tissue transfer. In all cases, collaboration with dental colleagues is necessary to ensure that reconstructive efforts do not hinder subsequent dental rehabilitation.

For larger defects, midface projection and support of exposed orbital contents must be considered. In general, vascularized tissue is preferable in the reconstruction of complex maxillectomy defects. Support of the orbit can be achieved with alloplastic materials, free bone grafts, or vascularized bone grafts. The use of free tissue is recommended because many of these patients have been radiated in the past or will receive adjuvant postoperative radiotherapy. The presence of well-vascularized tissue can decrease the risk of wound complications and eventually aid in the placement of implants for either dental rehabilitation or cosmetic purposes.

When planning a reconstructive strategy, the natural history of the disease must be considered and the reconstruction planned accordingly. Patients who are less likely to experience long-term survival or those with extensive comorbidities are generally considered for less invasive reconstruction.

Table 34–2 Reconstructive Options for Maxillectomy/Midface Defects

<table>
<thead>
<tr>
<th>Obturation</th>
<th>Free tissue transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local flaps</td>
<td>Fasciocutaneous</td>
</tr>
<tr>
<td>Palatal island</td>
<td>Radial forearm</td>
</tr>
<tr>
<td>FAMM</td>
<td>Scapular/parascapular</td>
</tr>
<tr>
<td>Pedicled flaps</td>
<td>Myocutaneous</td>
</tr>
<tr>
<td>Pectoralis major</td>
<td>Latissimus dorsi</td>
</tr>
<tr>
<td>Latissimus dorsi</td>
<td>Rectus abdominis</td>
</tr>
<tr>
<td>Trapezius</td>
<td>Osteocutaneous</td>
</tr>
<tr>
<td>Posterior scalping</td>
<td>Fibula</td>
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<td></td>
<td>Scapula</td>
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<tr>
<td></td>
<td>Iliac crest</td>
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<td></td>
<td>Osteomusculocutaneous</td>
</tr>
<tr>
<td></td>
<td>Tip of scapula/latissimus dorsi</td>
</tr>
<tr>
<td></td>
<td>Iliac crest/internal oblique</td>
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</tbody>
</table>

FAMM, facial artery myomucosal.

Postoperative Care

Antibacterial packing is placed into the resulting cavity in all but the most limited resections, and it is removed ~72 to 96 hours postoperatively. If regular packing is used, patients should remain on antistaphylococcal antibiotics until all packing is removed.
Depending on the extent of tumor resection and the surgical reconstruction, feeding is resumed as soon as possible. Following a medial maxillectomy, a regular diet is resumed on the first postoperative day. Patients who have undergone resection of a significant proportion of their hard palate and alveolus are restricted to a soft diet in the immediate postoperative period. Patients requiring free tissue transfers are tube fed in the early postoperative period, although those with smaller fasciocutaneous reconstructions are occasionally fed during this time.

When orbital contents are manipulated as part of the operative procedure, minor visual disturbance, including blurring, diplopia, and epiphora, may occur temporarily. Assessment of visual acuity in the postoperative period is important, and progressive deterioration in acuity or worsening diplopia should alert the surgeon to a potential orbital complication.

Following a maxillectomy, most patients will remain with a resection cavity communicating with the nasal cavity and oral cavity. Collections of mucus and blood become encrusted and colonized by anaerobic bacteria, resulting in a foul smell, nasal obstruction, and discomfort. Patients should be instructed about cleaning and maintaining these cavities because the normal mucociliary apparatus is no longer able to clear secretions. In the initial months after maxillectomy, debridement of the cavity by the surgeon is necessary, in addition to saline spray and lavage.

Extended maxillectomies involving resection of the pterygoid apparatus and tumors extending into the infratemporal fossa can significantly interfere with muscles of mastication and result in long-term fibrosis, often exacerbated by adjuvant radiotherapy. Oral exercises for several months to prevent trismus are encouraged.

Conclusion

The future of maxillary surgery will continue to see advances in endoscopic surgery and reconstruction. Endoscopic skills have advanced as a result of endoscopic sinus surgery, and this technique has been applied extensively to benign intranasal and paranasal sinus disease. Because en bloc tumor resection is difficult to achieve with endoscopy, its application to cancer therapy is controversial. However, the role of endoscopic surgery will continue to expand and may be combined with an open approach to improve visualization.

Ablative surgery for diseases of the maxilla can present challenges to the surgeon at many levels: diagnosis, investigation, resection, and reconstruction all demand a level of expertise to provide appropriate care. Knowledge of the anatomy, physiology, and pathology of this complex region is necessary to maximize survival and postoperative function.

Reference

Repair of Cerebrospinal Fluid Leaks

Alan P. Johnson

This chapter focuses solely on surgical management of cerebrospinal fluid (CSF) rhinorrhea. The impetus behind surgical repair of CSF leaks is prevention of meningitis. The risk of meningitis in CSF rhinorrhea is of the order of 1% per week while the leak is occurring. Surgery is indicated if conservative measures fail to control the leak.

◆ Preoperative Considerations

Diagnosis

◆ The analysis of liquid for the presence of tau protein or transferrin is highly specific and sensitive for CSF and is now the diagnostic test of choice.
◆ Glucose is present in CSF but not nasal mucus, but analysis for glucose is significantly less sensitive and specific and should not be used to confirm or refute the diagnosis.

Localization of Site of Leak/Imaging

◆ The key to successful repair of a CSF leak is identifying the source. If this can be achieved, and the site is accessible through the nose, the chance of repairing the leak from below is very high (>90%).
◆ CT scan Intrathecal contrast can be used with CT to demonstrate a leak, but this has mainly been replaced by the techniques described below.
◆ MRI scan Will demonstrate soft tissue defects and herniation of intracranial contents into the nose, sinuses, or temporal bone. T2-weighted sequences demonstrate CSF.
Intrathecal fluoroscine. This allows direct observation of the leak. If the fluoroscine is given immediately prior to surgery, the surgeon can explore the nose and sinuses endoscopically and identify the leak. Caution is needed because convulsions can occur with intrathecal fluoroscine.

**Surgical Principles**

- Identify the leak.
- Define all the margins of the defect.
- Dissect the dura off the deep aspect of the bone defect to develop a plane between the skull and dura.
- Insert a patch through the bone defect. The intracranial pressure of the brain, meninges, and CSF then press on the patch to hold it in place and seal the defect (Fig. 35–1).
- An additional mucosal graft may be applied to the nasal aspect of the repair as a further seal.
- Packing is used to support the graft until it is “stuck” in place.

**Surgical Approaches**

- Approaches include endoscopic, microsurgical, and direct vision using a headlight, either transnasally or via an external incision, in combination with endoscopes, a microscope, or both.

![Figure 35–1 Repair of cerebrospinal fluid leak using bone, fascia, and turbinate mucosa.](image-url)
The key consideration in this surgery is to identify the CSF leak and effectively repair it. Usually this can be done endoscopically or, if the line of vision is direct, with the microscope. Occasionally an external incision around the medial aspect of the eye or above it may improve access to the anterior ethmoid or frontal sinuses and make the operation easier.

Surgical Technique

The nose should be prepared by vasoconstriction.
The scans must be available to the surgeon, who needs to have a definite idea about the location of the leak unless intrathecal fluorescein is being used to define this.
Leaks into the ethmoid cells can be exposed by opening the ethmoid cells to expose the floor of the anterior cranial fossa.
Leaks in the cribriform plate may extend into the ethmoid cells, but if visible when the middle turbinate's superior attachment is still in place, the same principle applies: The margins of the bone defect should be defined by removing whatever intranasal bone structures are obstructing the view.
Access to a leak in the sphenoid sinus depends on its precise location. If the leak is in the roof of the sinus, removing the anterior wall and, if necessary, the rostrum of the vomer and the anterior wall of the other sphenoid sinus will expose the leak, which can be repaired by the technique described. If the leak is into the lateral recess of a well-aerated sphenoid sinus, gaining access can be a serious challenge. This is a very rare problem.
Sometimes exposure of the sinus, removal of as much mucosa as possible, and packing the sinus with muscle or Tisseal® glue, or both, is sufficient to stop the leak. If not, an approach from the contralateral side of the nose and the use of 30 and even 70 degree angled endoscopes may allow the leak to be seen and material to be packed through the defect (Fig. 35–2).
Leaks into the frontal sinus, particularly if away from the midline, may be inaccessible from the nose endoscopically. A small incision in the eyebrow and medial to the eye and a bone window in the floor of the frontal sinus will allow access, and the repair is thenachievable as elsewhere.
Having identified the defect, it is necessary to clear bone margins. Dissect the dura off the edge of the bone on the cranial side of the defect.
A graft is used to plug the defect. A whole range of materials is available to the surgeon; an autograft is preferable to any other tissue graft. A combination of soft tissue, such as fat, muscle, fascia, mucosa, and hard tissue, such as bone or cartilage, is preferred. Turbinate can be used as a combined bone and soft tissue graft. The graft is partially inserted through the defect. The bone needs its largest dimension to be greater than the smallest dimension of the bone defect so that it can be inserted and rotated or flattened to engage on the skull inside the defect and act as a support for the intracranial tissue. Ideally, it should lie intracranially and extradurally, wrapped in a fascial plug (Fig. 35–1).
An additional mucosal graft can be used on the nasal side and packed into place.

Synthetic materials, such as gelatin or collagen foam or sheet, can be used at any stage of the repair, but they are less effective if used alone rather than with an autograft.

Tissue glue may be useful to seal the area and can be used at several stages, but it too is less effective used alone than with an autograft.

At the end of the procedure, a pack should be carefully positioned to keep the graft in place and to maintain sterility. Bismuth and iodoform paraffin paste (BIPP) remains an incredibly good pack because of its highly antibacterial properties. The pack should stay in place long enough for the nasal graft to stick firmly in place. The author’s preference is for at least 5 days.

Postoperative Management

Covering the patient with antibiotics is sensible, because the surgeon is operating from a contaminated field into a sterile one. An appropriate antibiotic should be administered on induction of anesthesia so that it is circulating at effective levels when the defect is being manipulated and the graft placed. If a good closure is obtained, only one or two further doses of antibiotics should be necessary, but a 5-day course is reasonable to cover the presence of a pack in the nose.
The pack should be removed at 5 to 7 days, by which time the repair should be stuck in place.

The patient should be warned not to blow his or her nose, and if sneezing, to “let it out” so that there is not a sudden rise in intranasal pressure, which could force air or mucus through the defect into the brain. Similarly, the patient should avoid straining, as this raises the CSF pressure, which could encourage CSF leakage.

Some authors recommend the use of a lumbar drain to lower CSF pressure, but given the principles of the repair described above, this could be a disadvantage, and the author has never found a lumbar drain helpful.

**Complications**

- **Meningitis**  This is always a risk. Any preexisting sinus disease should be treated preoperatively, and it is wise to cover the procedure with an antibiotic, as stated.
- **Persistence or recurrence of the leak**  Should this happen, it is important to analyze why, as far as possible. If accessing or defining the margin of the leak was difficult, an extracranial transnasal approach is possible and should be considered if it will make the repair easier. The challenge of a leak into the lateral recess of the sphenoid and some options on how to approach this are described above. If a closure cannot be achieved from below for technical reasons, repair from above has to be considered, although this can also be difficult in the region of the sphenoid. If an initial repair is unsuccessful, it is well worth repeating the operation transnasally if the surgeon is confident that the leak can be identified and is accessible because the morbidity of this approach is low and a transnasal approach is much less invasive than a transcranial repair.
Local Flaps, Regional Flaps, and Free Tissue Transfer

Daphne A. Bascom

◆ Local Skin Flaps

Vascular Anatomy

◆ Local flaps are classified by blood supply and tissue movement.
◆ Random flaps are the type most commonly employed in the head and neck and are based on the rich perforating vascular plexus of the skin. The survival of random pattern flaps is unpredictable because of their blood supply.
◆ Axial pattern flaps derive their blood supply from a direct cutaneous artery or named blood vessel. Axial flaps can be of greater length-to-width ratios than random flaps because of their more predictable blood supply.

Surgical Technique

◆ It is often helpful to use a template to determine the best donor site.
◆ Before incising the flap, carefully undermine the defect site to ensure that primary closure is not possible.
◆ Incise and undermine the flap, then rotate, advance, or transpose it into the defect.
◆ Stabilize the flap with several key sutures, then inspect the flap perfusion.
◆ Close the donor site to minimize tension at the defect site.
◆ Remove any tissue redundancies after the flap is inset.
◆ Once adequate coverage, perfusion, and location have been ensured, sequentially remove the tacking sutures and begin final closure.
Flap Types

Rotation Flaps

- The rotation flap is curvilinear in shape and is designed to rotate about a fixed axis into the defect.
- A standing cutaneous deformity at the base of the flap is common.
- This can be addressed with a Burow's triangle; in some cases, over time, tissue contraction alone will eliminate the “dog ear.”

Transposition Flaps

- Transposition flaps are harvested at one site and transferred to a site immediately adjacent to the base of the flap.
- These differ from rotation flaps in that their final axis is linear, whereas the rotation flap has a curvilinear axis.
- The most important element of design of a transposition flap is the location of the pivot point.

Rhomboid and Dufourmentel Flaps

- The rhomboid flap is based on four equal sides with corresponding 60 and 120 degree angles.
- The Dufourmentel flap is one of several modifications of the rhomboid flap has angles varying from 60 to 90 degrees.
- Based on the flap design, there are four potential donor flaps from which to choose in order to align the final scar in an inconspicuous fashion.

Bilobed Flaps

- Bilobed flaps are double transposition flaps that share a single base.
- The primary flap is used to repair the surgical defect and the secondary flap to repair the flap donor site.
- Arcs of transposition of 90 to 110 degrees help to decrease the resulting deformity.
- A disadvantage of the bilobed flap is that the resulting scar may be unable to follow skin tension lines.

Advancement Flaps

- The basic design of an advancement flap is to extend an incision along parallel sides of the defect and then directly advance the tissue over the defect.
- Complete undermining of the advancement flap, as well as the skin and soft tissue around the flap pedicle, is key to successful tissue transfer.
- The classically designed advancement flap has a flap length-to-width ratio of approximately 1:2. Tissue is advanced a distance that approximates the width of...
the flap. Advancement beyond this length is possible; however, the tension on the flap may compromise distal blood flow.

- Standing cutaneous deformities are created when advancement flaps are used and usually require excision, accomplished by the removal of Burow’s triangle. Burow’s triangle excisions should never be performed before the flap is advanced into position because redundancy may be minimal, and resection may be unnecessary.

- Types
  - Monopedicle
  - Bipedicle

- The bilateral advancement flap is typically made when a single-pedicle advancement flap does not allow sufficient tissue for closure of the defect. A disadvantage of this flap is the potentially long suture line.

◆ Free Tissue Transfer

- Advantages
  - Availability of various tissue types for reconstruction: skin, soft tissue, muscle, and bone
  - Ability to reconstruct three-dimensional defects
  - Provides for immediate restoration of cosmesis and function
  - Potential for neurosensory restoration

- Disadvantages
  - Operative time and technical demands
  - 5% flap failure rate
  - Donor site morbidity

Preoperative Planning

- Amount and type of tissue required
- Benefit of neurosensory restoration
- Expected functional restoration
- Donor site morbidity
- Patient positioning and donor site location: potential for two-team surgery

Intraoperative Considerations

- Check microscope function prior to each case.
- Ensure all necessary supplies are in the operating room (OR) or close at hand.
Postoperative Management and Care

◆ Keep patient’s head in a neutral position to avoid tension on the anastomosis.
◆ Maintain close monitoring of hemodynamic status and hematocrit.
◆ Flap evaluation: Clinical evaluation is key. Although there are currently a number of external and indwelling devices that can be used to provide early signs of flap compromise, none of these devices is failsafe, and knowledgeable clinical assessment remains the standard.
  ◦ Color  A healthy flap is pink, exhibits good turgor, and has a capillary refill time of 1 to 3 seconds.
  ◦ Prick test  Pricking the flap with a 22-gauge needle should result in several drops of bright red blood.
  ◦ Ninety percent of all flap failures are associated with inadequate venous outflow or venous thrombosis. A flap with venous compromise will appear dark blue and congested, and the prick test will result in the rapid flow of venous (dark) appearing blood. Arterial insufficiency is manifest as a pale, cold flap with no flow of blood in response to the prick test. In both cases, flap salvage necessitates prompt return to the OR and exploration of the pedicle.

Pharmacotherapy

◆ Avoid pressors: substitute volume unless this will impact morbidity/mortality.
◆ Anticoagulation remains controversial, and its use is based on surgeon preference.
◆ Antiplatelet agents: aspirin
◆ Dextran is used to lower blood viscosity and inhibit rouleaux formation. It has been associated with perioperative pulmonary edema.
◆ Heparin and Lovenox (enoxaparin) are useful anticoagulants; however, their use may be associated with an increased risk of hematoma.
◆ Most of these agents are continued until day 3 postoperatively. Continuing them until the patient is mobile will also help safeguard against deep venous thrombosis (DVT) and pulmonary embolism.

Antibiotics

◆ Surgeon preference for clean-contaminated or contaminated head and neck procedures

Delirium Tremens Prophylaxis

◆ Delirium tremens in the postoperative period is associated with a higher incidence of flap loss and perioperative morbidity and mortality.
Flap Types

Radial Forearm Free Flap

- Vascular supply: radial artery and paired venae comitantes
- Advantages
  - Thin skin with long, large vascular pedicle
  - Easy positioning for two-team harvest
  - Potential for sensate flap using antebrachial cutaneous nerve
  - Potential for vascularized bone attached to flap
- Disadvantages
  - Low potential for loss of hand (must ensure ulnar system is patent with Allen’s and/or Doppler test)
  - Donor site defect cosmetically unappealing
  - Donor site usually requires skin graft for closure
- Must ensure fascia is covering tendons to prevent loss of function
- Potential for pathologic fractures when bone is taken; perioperative orthopaedic consultation is advisable.

Scapular/Parascapular Free Flap

- Vascular supply: circumflex scapular artery and accompanying venae comitantes
- Advantages
  - Fasciocutaneous flaps, which can be harvested independent of bone
  - Large skin paddle that is easy to harvest
  - Low donor site morbidity
  - Possibility for including scapula for necessary bony reconstruction
- Disadvantages
  - Thicker skin
  - Difficult positioning for two-team harvest

Lateral Arm Free Flap

- Vascular supply: posterior radial collateral artery and venae comitantes
- Advantages
  - Low donor site morbidity
  - Easy positioning and two-team harvest
  - Potential for sensory innervation from the lower lateral and posterior cutaneous nerves
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- Disadvantages
  - Short and small-caliber artery (1.8 mm average)
  - Thick subcutaneous tissue

Rectus Abdominus Free Flap

- The rectus abdominus can be harvested as a muscle flap, a musculocutaneous flap, or a musculoperitoneal flap.
- Vascular supply: deep inferior epigastric artery and venae comitantes
- Advantages
  - Easy positioning and harvest
  - Long and large-caliber pedicle
  - Donor site can be closed primarily with minimal donor defect.
  - Large flap can be obtained.
- Disadvantages
  - Often bulky
  - Potential for hernia formation, particularly if dissection is below the arcuate line

Latissimus Dorsi Free Flap

- Vascular supply: thoracodorsal artery and vein
- Advantages
  - Large flap (20 × 40 cm) with long pedicle
  - Low donor site morbidity
  - Possibility for muscle reinnervation via the thoracodorsal nerve
- Disadvantages
  - Difficult positioning and two-team harvest
  - Postoperative seroma formation common
  - Can be very bulky

Jejunum Free Flap

- The jejunum provides an abundant supply of mobile (must ensure that flap is placed in an isoperistaltic fashion), mucus-producing tissue useful for oropharyngeal and pharyngoesophageal reconstruction. Unlike other free flaps, the jejunal flap is inset prior to microvascular reanastomosis. This is to allow accurate three-dimensional placement of the vessels to minimize tension. It also prevents bleeding at the flap edges, which can complicate the flap inset, particularly when there is an anastomosis that must be performed in the thorax.
- Vascular supply: superior mesenteric artery and paired venae comitantes.
Advantages
- Tubular
- Mucosal surface
- Minimal donor defect

Disadvantages
- Need for laparotomy and bowel preparation
- In the past, flap harvest required a laparotomy. Some centers are now employing laparoscopic flap harvest to minimize donor site morbidity.
- Short pedicle
- The jejunal flap does not neovascularize and is hence totally dependent on its blood supply. Reports of flap loss several years after the initial procedure can be explained by this phenomenon.
- Poor tracheoesophageal speech: due to the mucus production, voice restoration results in a moist, gurgly voice.

Contraindications
- Ascites
- Previous abdominal surgery(ies) resulting in extensive abdominal adhesions
- Involvement of the thoracic esophagus
- History of chronic intestinal disease

Fibula Free Flap

Advantages
- Low donor site morbidity
- Easy positioning for two-team harvest
- Longest and strongest bone stock
- Excellent periosteal blood supply, allowing contouring of bone Easily supports osseointegrated dental implants

Disadvantages
- High incidence of lower extremity vascular disease and anomalies
- The variability in blood supply is one reason this flap may not be acceptable in certain patients. Aberrations in blood supply to the foot can occur in up to 10% of the population, with the peroneal artery being the dominant vessel to the entire foot. In order to verify this is not the case preoperatively, it is necessary to have an imaging study of the lower extremity vasculature (i.e., an angiogram or magnetic resonance angiography [MRA]).
- Limited cutaneous paddle
- Small chance of chronic ankle pain
Iliac Crest Free Flap

- Vascular supply: deep circumflex iliac artery and vein

- Advantages
  - Thick bone stock
  - Facilitates dental restoration with osseointegrated implants
  - Easy positioning for two-team harvest
  - Defect closed primarily
  - Minimal donor deformity

- Disadvantages
  - Bulky soft tissue component
  - Decreased postoperative ambulation may increase risk of DVT
  - Possible risk to peritoneum and bowel during flap harvest
Facelift, Blepharoplasty, and Facial Rejuvenation Procedures

Robin M. Brody

◆ General Approach

◆ One may combine modalities or plan on using several modalities as a staged approach for facial rejuvenation.
◆ Preoperative photodocumentation is important for accurate comparison of pre- and postoperative results, as well as for medicolegal reasons.

◆ Facelift (Rhytidectomy, Rhytidoplasty)

Preoperative Considerations

◆ Anatomical considerations include platysmal banding (“turkey gobbler deformity”), jowls, position of malar fat pad, bone resorption (may indicate the need for concomitant anatomical implants, e.g., chin implant or prejowl chin implant), prominent nasolabial folds, and skin laxity.
◆ Smoking cessation should be encouraged because smoking increases the risk of flap necrosis and hematoma formation.
◆ Hairline and hairstyle are important in the planning of incisions.

Surgical Technique

Facelift Incisions

◆ A temporal incision is made ~5 cm posterior to the hairline, emerging in the preauricular region in a natural skin crease along the anterosuperior helical fold, posterior to the sideburn.
In males, the incision continues inferiorly toward the lobule, in a skin crease that is posterior to the sideburn. This prevents advancing the sideburn into the ear. In women, a post-tragal incision is made.

The incision then curves posteriorly and superiorly in the posterior aspect of the conchal bowl, a few millimeters lateral to the postauricular sulcus.

Posterior extension of the incision at the level of the antihelix is performed, onto the scalp toward the region of the mastoid, then toward the occipital scalp, posterior to the hairline.

If a submental liposuction and/or platysmaplasty are performed, the incision is marked in the region of the natural submental crease.

Local anesthesia, vasoconstriction, and hydrodissection are accomplished with subcutaneous infiltration of 2% lidocaine with 1:200,000 epinephrine along the incision sites and 1% lidocaine with 1:200,000 epinephrine along the flap.

Platysmaplasty

Submental liposuction is performed in the preplatysmal plane to the level of the thyroid cartilage inferiorly and to the region of the submandibular glands laterally. Subcutaneous tunnels are connected.

Medial margins of the dehiscent platysmal muscles with a portion of its intervening fat are identified and held with a heavy clamp. A no. 15 blade is used to excise a small portion of the medial bands and fat. The cut edges are then sewn from inferior to superior, using either interrupted or a running locking suture.

Surgical Approaches

Skin Lift

The skin flap is raised in a subcutaneous plane, trimmed, and repositioned.

This approach is rarely used because it does not take into account the underlying muscular laxity and the multiple vectors involved in facial laxity.

SMAS Plication/Imbrication

A skin flap is raised.

The submuscular aponeurotic system (SMAS) is plicated or imbricated with permanent sutures to tighten redundancy and alter the vector of pull.

The skin is redraped in an appropriate vector and sutured without tension. The superior suture is in a posterosuperior direction, and the inferior cheek suture is directed posterior toward the lobule.

Skin in the region of the tragus is defatted to better define the tragus.

Advantage

Simple and safe, with minimal postoperative edema

Disadvantage

May not adequately address the malar fat pad and/or nasolabial fold
◆ Deep Plane

◆ An incision is made through the SMAS in the malar region and continued inferiorly toward the posterior border of the platysma, just below the angle of the mandible.
◆ The SMAS is dissected from the deeper parotidomasseteric fascia with vertical spreading motions of the scissors.
◆ In the region of the nasolabial fold, remain in plane superficial to the zygomatic muscles to prevent injury to the branches of the facial nerve.
◆ The jowl area is bluntly undermined in the fibrofatty plane over the masseter. At the anterior border of the masseter, the masseteric-cutaneous ligaments are sharply transected.
◆ In composite rhytidectomy, the deep plane technique is extended deep to the orbicularis oculi muscle such that the flap is elevated in a subperiosteal plane. This allows for superior repositioning of the malar fat pad.

◆ Advantage
  ◦ Better addresses regions of the malar fat pad and nasolabial fold

◆ Disadvantages
  ◦ Technically more difficult to perform with prolonged operative time and prolonged postoperative edema
  ◦ Increased risk of injury to the facial nerve

Postoperative Management

◆ Drains may or may not be necessary; fibrin glue may be used as tissue sealant to obviate the need for drain.
◆ A pressure dressing is applied, but avoid excessive pressure.
◆ Cold compresses are applied.

Complications

◆ Infection: rare in the face as a result of the rich blood supply
◆ Hematoma: important to identify and evacuate early to minimize the risk of skin necrosis. Expanding hematomas may require operative evacuation and control of hemorrhage. Small, old hematomas may become evident in the later postoperative period as facial edema decreases. These may be evacuated as they liquefy with a 20- or 22-gauge needle on a syringe.
◆ Skin necrosis: increased risk in smokers secondary to compromise of vascular supply; may also result from excessive tension on wound closure or from a flap that is too thin. No debridement should be performed until the wound has marginated and the eschar has begun to slough on its own, as the eschar will act as a biological dressing. This is seen most commonly in the postauricular area.
◆ Facial nerve paresis/paralysis: theoretical increased risk with deep plane facelifts (but this may be the result of a “learning curve”)
Hypertrophic scars: these are wide and/or raised scars that are often pruritic; may result from excessive tension on wound closure. Treatment involves steroid injection and possibly scar revision.

Pixie ear deformity.

**Blepharoplasty**

**Preoperative Considerations**

- Skin laxity and fat should be determined.
- Assessment of temporal (lateral), central (middle), and nasal (medial) fat pads with central gaze, superior gaze, and with gentle pressure applied to the globe.
- Brow appearance: heavy or ptotic brow may warrant concomitant brow lift.
- Lower eyelid position, lid distraction, and “snap” test: position of lower eyelid may dictate that a lower lid–tightening procedure (canthoplasty, canthopexy) be performed at the time of a lower blepharoplasty to prevent postoperative ectropion.
- Schirmer’s test should be performed to identify patients with dry eye. Normal Schirmer’s testing would indicate 10 to 15 mm of wetting in 5 minutes.
- Visual acuity should be documented.

**Surgical Techniques**

*Upper Blepharoplasty*

- The incision is marked. The lower marking is placed in the lid crease that is created with slight upward gaze (usually 7–10 mm from the lash line), starting nasally just above the punctum and extending 1.0 to 1.5 cm beyond the lateral canthus. Forceps are used to pinch the skin superior to the marking, and a mark is placed at the level that eliminates the excess skin, everts the lashes, and minimally elevates the upper lid. This corresponds to the upper skin incision.
- Local anesthetic with vasoconstriction is injected for local anesthesia, hemostasis, and hydrodissection with or without hyaluronidase (Wydase).
- The skin is incised with a no. 15 blade, and subcutaneous elevation is performed to excise the outlined skin excess.
- Gentle pressure is applied to the globe, and any protrusion of the orbicularis muscle nasally is grasped and incised (or excised); any prolapsing nasal fat (white in color) is clamped and excised, and hemostasis is achieved. This is repeated in the region of the middle fat pad (yellow). There is no temporal fat pad in the upper eyelid.
- An alternative is excision of a strip of orbicularis muscle.
- Skin is closed with a running subcutaneous 6–0 Prolene pull-out suture.

*Lower Blepharoplasty*

- Mark all three fat pads (nasal, central, and temporal).
- If performed in conjunction with upper blepharoplasty, one must have at least 5 mm of skin between the upper and lower lateral canthal incisions to prevent contracture.
Skin–Muscle Flap

- Useful when there is excess skin and fat
- A subciliary incision is made 2 to 3 mm below lash line, beginning nasally below the punctum and extending temporally to 1 cm beyond the lateral canthus.
- A traction suture is placed through the skin, orbicularis, and tarsus to pull the lower eyelid upward and to protect the globe.
- Suborbicularis dissection creates a skin–muscle flap and allows visualization of the fat pads.
- An incision is made through the capsule of the temporal fat pad, and retropulsion of the globe is used to identify and sequentially excise the prolapsed temporal, central, and nasal fat pads (the inferior oblique muscle separates the central and nasal fat pads).
- The traction suture is removed, the skin–muscle flap is redraped, skin redundancy and a strip of orbicularis are excised (excise 1–2 mm more of muscle than skin to prevent bulging), and the incision is closed with running nonabsorbable suture.

Skin Flap

- Similar to above technique except this is a “skin only” flap, and orbicularis muscle is incised to access fat

Transconjunctival

- Useful when excess fat is present, but there is little to no excess skin (but may be combined with skin-pincheblepharoplasty)
- Topical tetracaine drops and scleral lens are placed, followed by subconjunctival injection of local anesthesia and hemostasis.
- A conjunctival incision is made just above the fornix with a Colorado needle, and continued through Müller’s muscle and the capsulopalpebral fascia until fat is encountered.
- The orbital septum is incised, and prolapsed postseptal herniated fat is grasped and sequentially excised and cauterized from temporal to nasal.
- The conjunctiva may or may not be reapproximated.

Complications

- Lagophthalmos (inability to completely close eye secondary to excessive skin resection), ectropion, hematoma (requires immediate evacuation with or without cantholysis), dry eye, and epiphora.

Brow Lift

Preoperative Considerations

- The ideal brow position begins at a vertical line drawn from the alar-facial groove to the medial canthus and ends at the diagonal line drawn from the alar-facial
groove to the lateral canthus. The medial and lateral aspects of the brow should rest at the same horizontal height.

- In females, the brow should have a gentle arch just above the supraorbital rim. In males, the brow position is flatter and rests at the level of the supraorbital rim. The highpoint is located at the vertical line drawn just lateral to the lateral limbus.

### Surgical Techniques

#### Incision

- **Coronal forehead lift**  A coronal incision is made 4 to 6 cm behind the anterior hairline, followed by anterior subgaleal dissection to the level of the supraorbital rims and lateral dissection on the deep temporalis fascia, then removal of a strip of hair-bearing scalp. Disadvantages of this technique include scalp hypesthesia and hairline elevation.
- **Pretricheal forehead lift**  Incision is just anterior to the hairline.
- **Trichophytic forehead lift**  Incision is 2 mm posterior to the hairline.
- **Midforehead lift**  Incision is in a natural midforehead crease; dissection is above the galea, then subgaleal, followed by removal of a strip of forehead skin.
- **Direct forehead lift**  Excision of a wedge of skin and subcutaneous tissue is done above each eyebrow.

#### Endoscopic

- Multiple techniques, all involving the following:
  - Anesthesia with supraorbital and supratrochlear, block as well as direct infiltration for hydrodissection and hemostasis
  - Central, subperiosteal dissection of the scalp to the level of the orbital rims
  - Identification of the supraorbital and supratrochlear nerves to avoid postoperative paresthesia
  - Temporal dissection deep to the superficial temporal fascia (i.e., deep to the temporoparietal fascia) while staying above the superficial layer of the deep temporal fascia
  - Release of the conjoined fascia along the temporal line to connect the central and temporal pockets. Release should continue inferiorly to the level of the lateral canthus and onto the takeoff of the zygomatic arch. Stay medial and subperiosteal to avoid injury to the frontal branch of the facial nerve, which crosses the arch midway between the tragus and the lateral canthus (“danger area”).
  - “Sentinel vein,” a branch of the zygomaticotemporal vein located at the level of the frontozygomatic suture, is a reliable marker for the facial nerve.
  - Myotomies or myomectomies of the brow depressors: procerus, corrugator, and depressor supercilii
  - Repositioning of the brow and fixation that is either temporary (including removable screws, absorbable sutures) or permanent (including subcortical bone tunneling, suturing, and screw fixation)
Advantages

◆ Incision sites not visible (can be used in bald patients and those with thin hair)
◆ Avoids postoperative numbness and paresthesia
◆ Less alopecia

Skin Resurfacing

◆ Improves skin texture and appearance by replacing damaged skin with new epidermis and collagen. The pilosebaceous unit is responsible for reepithelialization.

Preoperative Considerations

◆ Determine Fitzpatrick skin type: classification scale based on skin pigmentation and response to sun exposure, ranging from type I (white skin, always burns) to type VI (black skin, never burns).
◆ Determine Glogau skin type: classification scale based on degree of wrinkling, ranging from type I (mild actinic changes, no wrinkles) to type IV (severe actinic changes, only wrinkles).
◆ Look for dyschromias.
◆ Determine skin texture: may alter pretreatment regimen and type (depth) of resurfacing. Thick, oily, sebaceous skin may require aggressive pretreatment regimens with retinoids and α-hydroxyl acids. Thin, dry, atrophic skin will require preoperative moisturization.
◆ If the patient has acne, Accutane therapy must be discontinued prior to peel.

Techniques

Dermabrasion

◆ A rotary burr is used to abrade or surgically plane the skin, which has been pretreated with a refrigerant spray. The depth of exfoliation is controlled by visually controlling the depth of dermabrasion.
◆ Avoid abrading beyond reticular dermis to prevent scarring and hypopigmentation.
◆ Uses: acne scars, traumatic scarring, deep rhytids, rhinophyma
◆ Disadvantage: potential airborne pathogens

Chemical Peels

◆ Superficial peels
  ◦ α-hydroxy acid, tretinoin, Jessner’s solution, trichloroacetic acid (TCA) 10 to 35%
  ◦ Accelerates slough of stratum corneum and stimulates growth of epidermal layer
  ◦ Uses: fine rhytids, actinic and pigmentary changes
Medium peels
- TCA 35 to 50%, phenol 88%

Deep peels
- Baker-Gordon phenol
- Medium and deep peels cause inflammation and necrosis in the papillary and upper reticular dermis to stimulate the production of collagen.
- Concentration of phenol is inversely proportional to the depth of peel.
- Adequate hydration and cardiac monitoring are necessary with the use of phenol to avoid hepatic and renal toxicity and to monitor for arrhythmias secondary to potential cardiac toxicity.

Laser
- Carbon dioxide
  - Controlled thermal injury to the upper reticular dermis promotes new collagen production, and a zone of reversible thermal injury induces collagen contraction.
- Erbium
  - Advantage: less thermal damage and faster recovery.
  - Disadvantage: less collagen contraction and skin tightening than carbon dioxide.

Postoperative Management
- Multiple regimens exist, most employing postoperative emolliation until reepithelialization is complete.

Complications
- Infection Minimized by prophylactic use of antibiotics and antiviral agents against herpes. Antibiotic therapy against Staphylococcus, Streptococcus, Pseudomonas, and gram-negatives is also employed.
- Prolonged erythema Treat with topical steroid cream.
- Hyperpigmentation May result from prolonged erythema and/or infection, inappropriate Fitzpatrick skin type. Treat with bleaching agent such as hydroquinone.
- Hypopigmentation May result from excessive depth of peel. Treat with camouflage agents.
- Scar formation Secondary to deep dermal injury or poor postop wound care. Treat with intrallesional steroids and/or scar revision.
Otoplasty

John S. Rhee

◆ Surgical Anatomy

◆ Surface anatomy
  ◦ The longitudinal axis of the ear should recline 20 degrees from the vertical plane.
  ◦ The auricle is normally 5 to 6 cm in length.
  ◦ The width of the ear should be 55% of the length.
  ◦ The angle of protrusion (auriculomastoid angle) should be 15 to 30 degrees.
  ◦ The helical rim is normally 15 to 20 mm from the mastoid scalp.

◆ Categories and Definitions

Outstanding, Prominent, or Protruding Ear

◆ These terms are often used synonymously to describe the most common anatomical deformity: the lack of development of the antihelical fold with or without a deep conchal bowl.

Lop Ear

◆ Characterized by a thin, flat ear with the helix acutely folded downward at the superior pole
Cup Ear

- Characterized by a smaller than normal ear with weak cartilage, resulting in a cupping or deepening of the conchal bowl.
- There is poor development of the superior pole with a short, thickened helix and deformed antihelix.

The surgical considerations and techniques outlined below are more applicable to the more common protruding ear deformity. Correction of other auricle deformities is beyond the scope of this chapter, but certain portions of the outlined techniques can be used for other auricle malformations.

**Preoperative Considerations**

- Optimal age for otoplasty is between 4 and 6 years for the following reasons
  - Auricle is near adult size.
  - Psychological distress associated with peer ridicule at school is minimized.
  - Child is capable of participating in postoperative care of ear.
  - Cartilage is soft and pliable.
- Features to note on physical examination
  - Antihelical fold absence
  - Conchal bowl size and projection
  - Lobule size and position
  - Right and left ear asymmetries
- Indications for surgery
  - Absence or poor development of antihelical folds with greater than 20 mm projection of helical rim from mastoid skin
  - Deep conchal bowl with auriculomastoid angle greater than 30 degrees
  - Asymmetrically projecting ears
  - Desire for correction
- Contraindications for surgery
  - Child under 4 years of age
  - History of keloid formation
  - Unrealistic expectations
- Photodocumentation
  - Standard frontal, lateral, and oblique views
  - Optional posterior and close-up lateral views

**Surgical Technique**

There are essentially four steps to correction of the prominent ear. Depending on the deformity, not all four steps are necessary to achieve the optimal result.
Skin and Soft Tissue Excision

Two skin excision patterns are depicted in Fig. 38–1.

- An eccentric fusiform incision around the postauricular sulcus (Fig. 38–1A)

**Figure 38–1** Skin excision patterns. (A) Eccentric fusiform skin excision pattern. The dotted line indicates the optional releasing incision. (B) Dumbbell-shaped skin excision pattern.
Preferable in situations with very deep conchal bowls: Easier conchomastoid suture placement and soft tissue excision aid in conchal setback.

More tissue is removed from the auricle than the mastoid area.

Usually, the fusiform area is 10 to 12 mm at its widest point.

Dissection is taken down to the level of the perichondrium of the ear and the periosteum of the mastoid bone. Fat and postauricular muscle are excised with overlying skin.

Optional releasing incision may be necessary for placement of Mustarde sutures.

A dumbbell-shaped incision is made on the posterior aspect of the auricle (Fig. 38–1B).

Easier access to antihelical fold for placement of Mustarde sutures.

Conchomastoid suture placement is slightly more difficult.

Pattern of excision aids in preventing “telephone ear” deformity (see below in Complications).

Dissection is taken down to the level of the perichondrium of the ear.

Correction of the Deep Conchal Bowl

Prominent posterior eminence of the conchal cartilage can be shaved off (shape of small disks) using a scalpel. It is important that only a partial thickness excision is performed.

Conchomastoid sutures are placed in a horizontal mattress fashion using 4–0 mersilene (or clear nylon) suture in one or two locations to appose the conchal bowl to the mastoid periosteum (Fig. 38–2).

Reduces the auriculomastoid angle.

Synonymous terms for conchomastoid suture technique include Furnas technique and conchal setback.

Avoid rotation of the auricle anteriorly when placing sutures. This may result in external auditory canal narrowing.

Creation of the Antihelical Fold

Mustarde technique: Horizontal mattress sutures are placed in the auricular cartilage along the scapha to re-create the antihelical fold (Fig. 38–3).

4–0 mersilene or nylon suture on a P-3 cutting needle

Care should be taken to include full thickness of the cartilage and lateral perichondrium, but not the lateral skin.

Usually need 4 or 5 sutures

Knots should be tied sequentially from top to bottom after placement of all the sutures.

Care should be taken to re-create a natural curve to the antihelical fold. Over- or undertightening of the sutures will result in a suboptimal outcome.
Figure 38–2 Conchomastoid suture placement.

Figure 38–3 Mustarde suture placement.
Lobule Repositioning or Reduction

- Conchal setback may improve the lobule position.
- Overcorrection of the middle third of the ear via Mustarde sutures may worsen the lobule position.
- For further medialization, incision of the cauda helix or a horizontal mattress suture placed between the cauda helix and the inferior conchal cavum may be necessary.
- Lobule reduction may be necessary.

Hemostasis is obtained with cautery. The skin incision is closed in a single layer with interrupted 5–0 catgut suture. The opposite ear is then addressed. Achieving symmetry between the ears is of utmost importance. Antibiotic ointment is applied to the incision line. Cotton, saturated in mineral oil, is molded to the lateral surface of the ear, and a pressure dressing is applied. No drain is used.

Postoperative Management

- Check for hematoma formation on the first postoperative day.
- Leave pressure dressing on for 3 or 4 more days.
- A head band should be worn at night for the next 4 to 6 weeks.

Pitfalls and Complications

- Hematoma
  - Significant pain or “tightness” may indicate hematoma.
  - Early recognition and evacuation are essential to avoid chondritis and skin or cartilage necrosis.

- Infection
  - Perichondritis or chondritis may result in a permanent cosmetic deformity.
  - Antibiotics should cover *Staphylococcus aureus* and *Pseudomonas aeruginosa*.

- Hypertrophic scar or keloid formation
  - Treat with triamcinolone injections intradermally.

- External auditory canal stenosis
  - May result if conchomastoid suture is placed too anteriorly on mastoid.

- Aesthetic complications
  - Inadequate correction: Some loss of correction is to be expected. Rates of relapse of auricular projection range from 2 to 13%.
Asymmetry

Telephone ear deformity: results from overcorrection of the middle third of the ear

Reverse telephone ear deformity: results from overcorrection of the upper and lower poles of the ear

Lobule malpositioning
There is no single rhinoplasty operation, and for that reason the learning curve is a long and steep one. This chapter will attempt to highlight some of the more fundamental surgical maneuvers and concepts in basic rhinoplasty and nasal fracture surgery to serve as a basis on which one can build.

◆ Nasal Fracture Surgery

Preoperative Considerations

◆ **Timing of surgery**  Invariably, patients are told to see the ear, nose, and throat specialist “once the swelling is all gone.” Two problems can result from that approach. First, the diagnosis of a septal hematoma or abscess may be inadvertently delayed. Second, the patient may not show up for 10 to 12 days, at which point the need to intervene becomes more pressing, and the ability to “plan ahead” is lost. It is better to see patients early (within 3 days of injury) so that serious complications are recognized. If a closed reduction is felt to be necessary, there is then adequate time to work the case into one’s schedule without a sense of urgency. Closed reduction is ideally performed within 5 to 10 days postinjury.

◆ Patients should always be warned of the possibility of residual deformity and the need for secondary surgery before undergoing a closed reduction.

◆ Photographic documentation is helpful both as an accurate reminder of the preoperative state and to support the claim for future surgery should that be necessary.

◆ Indications for surgery include a septal hematoma or abscess (emergent), change in appearance, and change in breathing. If breathing is the only issue, and there is no appreciable change in appearance, this may be due to residual congestion or
swelling from the injury, and little is lost in waiting. Delayed septal surgery does not present the same degree of challenge as the delayed treatment of a crooked nose.

Surgical Technique

◆ Closed reduction is best performed under intravenous sedation or general anesthesia. Maximal patient comfort will make it easier to forcefully manipulate the nasal bones if necessary and optimize the chances for a successful reduction.

◆ The nose should be suctioned out and topically decongested. An Asch septal forceps, carefully introduced on both sides of the septum under the nasal bones, gives the surgeon excellent control of the entire nasal pyramid. The fractured and displaced nasal bones are then disimpacted (which often means initially continuing movement in the direction of the initial force of the injury) and repositioned to the midline.

◆ If there remains a focal unilateral lateral nasal wall depression, this can be repositioned using the Boies elevator (Goldman elevator) placed directly under the bone in question.

◆ Packing is not routinely used, but it is recommended for the very comminuted or unstable reduced nasal fracture. Rolled Telfa coated in an antibiotic ointment is much more comfortable for the patient. The nose may be packed from 1 to 5 days, depending on the degree of perceived instability.

◆ An external splint is not absolutely necessary, but it will often discourage the patient from palpation or manipulation of the nasal framework and is thus recommended for 5 to 7 days.

◆ Basic Rhinoplasty

Full coverage of the entire range of rhinoplasty principles and procedures is beyond the scope of this chapter. Instead, this chapter will focus on rhinoplasty fundamentals and the more common problems encountered, such as profile alignment, enhancement of nasal tip definition, and effecting changes in tip projection and rotation.

General Considerations

◆ Preoperative photographic documentation is essential. Standard facial views include a full frontal, right and left oblique, right and left lateral, and nasal base view. Close-ups are optional.

◆ Informed consent should include the risks of bleeding, intranasal scarring, worsening of the nasal airway, palpable or visible irregularities, asymmetry, failure to meet patient expectations, and the possible need for future revision surgery.

◆ Surgery may be performed under local anesthesia, intravenous sedation, or general anesthesia, depending on patient and surgeon preference. The latter two options are generally preferred.
In all cases, the nose is also injected at the time of surgery with 10 to 15 cc of 1% lidocaine with 1:100,000 epinephrine for additional hemostasis, and decongested with either oxymetazoline or 4% cocaine (maximum 5 cc) soaked pledgets. The minimum amount of local anesthetic to facilitate hemostasis without overly distorting the nasal appearance is recommended.

There is no absolute sequence for septal, tip, and dorsal surgery. It is more important to realize that all three are interrelated, and to understand and anticipate the impact that surgical maneuvers in one area may have on another.

Surgical Approaches

There are basically two approaches to the nose: endonasal and external. The most important determinant here is physician comfort level and experience. In general, more typical indications for an external approach would include complicated revision surgery, unclear anatomy, severe asymmetry, the need for sutured-in-place grafting, the crooked nose, and the cleft lip rhinoplasty.

Endonasal Approach

Access to the dorsum is obtained by elevating the overlying skin and soft tissue envelope through bilateral intercartilaginous (IC) incisions (at the junction of the upper and lower lateral cartilages, ULCs and LLCs, respectively) connecting to a transfixion incision along the caudal septum. Midline dissection should remain in the avascular plane intimate to the perichondrium of the dorsal septum and deep to the periosteum of the nasal bones. Elevate the skin and soft tissue envelope (using an Aufricht or Converse retractor) only as much as is necessary for good exposure to facilitate reduction or augmentation, because the periosteal and soft tissue attachments to the nasal side wall help provide support and protect from excessive medial collapse of the nasal bones.

Access to the nasal tip can be via IC incisions with retrograde dissection, or transcartilaginous (splitting the lateral crus of the lower lateral cartilage) incisions, but both of these imply more limited exposure/visibility and thus a higher risk of asymmetry. A third (and preferred) option if any significant tip surgery is planned endonasally is using an alar delivery approach, whereby the LLC is “delivered” or pivoted inferiorly through the nostril as a bipedicled chondrocutaneous flap (hinged medially and laterally) by combining IC incisions with a transfixion incision along the caudal septum (above the LLCs), and marginal incisions along the lower border of the LLC (below the LLC) on each side.

An IC incision is made by everting the alar rim with a wide two-prong hook, at which point the caudal border of the ULC is apparent as a “shelf.” A no. 11 blade is then used to make an incision between the ULC and the overlying skin, parallel to the plane of the ULC, between the cephalic margin of the LLC and the caudal border of the ULC. This incision is then carried medially over the dorsal cartilaginous septum and around the anterior septal angle to connect with a transfixion incision along the caudal septum.

The marginal incision is made by everting the alar rim and using a no. 15 blade to incise vestibular skin at the caudal border of the lower lateral cartilage, carefully
following that border from lateral to medial, beneath the dome of the LLC and along the columella, taking care not to incise the caudal border of the medial crura in so doing. The overlying skin and soft tissue are then dissected from the LLC, which can be pivoted or “delivered” inferiorly by retracting the LLC downward with a small hook.

External Approach

- Using this approach, access to the dorsum and tip is obtained by combining bilateral marginal incisions with a transcolumellar incision.
- The marginal incision is performed as one would for endonasal surgery.
- The transcolumellar incision is stairstepped or irregularized in some fashion to avoid a linear incision. This helps minimize the risk of scar visibility and contraction. Generally, the incision is made about midway along the columella, where the underlying medial crura lie close to the skin. Care must be taken not to transect the medial crura when making this incision.
- Using these incisions, a columellar skin flap is elevated together with the skin and soft tissue over the lower lateral cartilages, the middle nasal vault, the dorsal septum, and the nasal bones. Above the level of the alar cartilages, the anterior septal angle is identified, and cephalad dissection is performed in the plane intimate to the perichondrium of the middle third of the nose. Just above the caudal aspect of the nasal bones, the peristemeum is incised, and dissection transitions to a subperiosteal plane. By staying intimate to the perichondrium and periosteum, the elevation is performed in a relatively avascular plane, and there is minimal chance of inadvertently thinning the overlying soft tissue.

Profile Alignment

- The ideal profile in the male conforms to a straight line, from the nasofrontal angle to the nasal tip, leaving a strong, high profile.
- In the female, the goal is to establish a relationship between the tip and dorsum such that the most anterior point of the tip lies 2 to 3 mm above the cartilaginous dorsal profile to create an aesthetically pleasing supratip break.
- Life-size photographs can be generated by taking a digital lateral view photo with a ruler held just in front of the nasal tip, then enlarging the pictures as need be so that when printed, the same ruler matches that on the printed image millimeter for millimeter. This will allow the surgeon to draw on the printed image and take accurate measurements of the desired amount of the reduction to facilitate accuracy and better results.
- Although the adjustment of the dorsal profile may either precede or follow the nasal tip surgery, in cases with a particularly high cartilaginous dorsum primary dorsal reduction may be beneficial. In such cases, an apparently overprojected tip may in fact be “cantilevered” forward by the marked height of the nasal dorsum (the “tension” tip), and more accurate tip surgery may be performed by first allowing the tip position to settle after the overly high dorsum is reduced. In such circumstances, primary tip reduction may erroneously lead to an overreduction.
The cartilaginous dorsum is reduced using either a knife or angled (Foman) scissors. An effort should be made to preserve the integrity of the mucosa underlying the junction of the ULC with the cartilaginous dorsum because this helps to provide support to the ULCs and guard against medial collapse in the middle third of the nose.

For smaller dorsal reductions (1–3 mm), an incremental reduction may combine resection of the dorsal septal cartilage with the attached ULCs, without violating the underlying mucosa.

For more significant reductions, it is best to separate the ULCs from the dorsal septum before the dorsal reduction. This is done by continuing the submucoperichondrial dissection along the septum up to the undersurface of the ULCs, then separating the ULCs from the dorsal septum under direct vision (with an Aufricht or Converse retractor in place beneath the dorsal skin and soft tissue) using either a sharp periosteal elevator or a no. 11 blade and incising from beneath the ULCs (under the mucoperichondrial flap) toward the overlying retractor.

The height of the ULCs must be adjusted using a knife or scissors to match that of the dorsal septum to help create a smooth profile. In the external approach, the ULCs can be reattached to the dorsal septum after all profile adjustments are complete, using one or two horizontal mattress 5–0 polydioxanone (PDS) sutures, which incorporate the ULCs from both sides as well as the dorsal edge of the septal cartilage.

The cartilage reduction establishes the tip–supratip relationship, after which the reduction of the bony dorsum is performed with greater precision. Reduction of the bony dorsum may be performed with either tungsten carbide nasal rasps (for a minimal reduction or for a more incremental reduction in the hands of a less experienced surgeon) or an osteotome (for a greater reduction or for those more experienced).

Tungsten carbide rasps range from the very coarse (a no. 6, 7, or 8) to the very fine (a no. 1 or 2). Pull rasps (which cut on the downstroke from cephalad to caudal) are generally easier to manage than push rasps (which remove bone as one moves from a caudal to cephalad position). When using rasps, this author generally will start with a no. 5 or no. 6 for more aggressive initial bone reduction, then transition to a no. 4 or no. 3 for further bone removal, and finally a no. 2 or no. 1 to smooth out and polish any irregular edges.

Care must be taken with the use of the nasal rasps to orient the rasp obliquely and with a slightly anterior pull to prevent inadvertent avulsion of the ULC from its attachment to the caudal aspect of the nasal bone.

When using an osteotome, the flat, double-guarded Rubin osteotome is preferred. The Rubin osteotome has a small dorsal “fin,” vertically aligned perpendicular to the plane of the cutting edge. This helps the surgeon keep the osteotome properly aligned to the plane in which it is being advanced, minimizing the tendency to tilt to either side.

The osteotome is engaged at the caudal end of the bony hump (the cephalic cut edge of the cartilaginous reduction) and guided by the surgeon as it is advanced by the assistant using a mallet under the surgeon’s direction toward the nasofrontal angle. The bony segment, once fractured at the nasal radix, is then removed under direct vision.
It is better to slightly underreduce the bony dorsum, completing or fine-tuning the rest of the bony reduction with the nasal rasps. Inadvertent overreduction can be remedied with replacement of the resected bone (once reduced in size) or with an autogenous cartilage onlay graft.

Regardless of which technique is used for the profile alignment, the surgeon must be diligent in attending to any irregularities to ensure that the dorsal line is perfectly smooth.

Osteotomies

Osteotomies are used to narrow the nose, to correct the alignment of the nasal pyramid, and to close the “open roof” deformity that naturally results from a reduction of the bony dorsum. In the latter case, if not for the infracture of the nasal bones, the nasal dorsum would appear wide and flattened (the “open roof”) on frontal view. Complete osteotomies will mobilize and medialize the bony nasal side wall together with the attached ULCs. Osteotomies progress from medial to intermediate (when indicated); lateral osteotomies complete the infracture of the nasal bones.

Medial Osteotomies

Several kinds of osteotomes are available, and the choice will vary with surgeon preference. These may range from 2, 3, or 4 mm straight osteotomes to a 4 to 6 mm curved osteotome. Smaller osteotomes create less tissue trauma but require more skill to use.

The osteotome is positioned at the cephalic edge of the bony hump removal (at the apex of the open roof), alongside the septum in a parasagittal plane. From this point, the mallet advances the osteotome obliquely, 15 to 20 degrees from the parasagittal plane, upward to the level of the nasofrontal angle. A similar maneuver is performed on both sides of the septum.

If any kind of grafting is planned for the middle third of the nose (e.g., spreader grafts), it is best to perform the medial oblique osteotomy before the sutured-in-place grafting is performed so as not to disrupt the stable position of the cartilage graft in the process of performing the osteotomies.

Intermediate Osteotomies

Intermediate osteotomies are used less often. They are indicated to help narrow an extremely wide nose, to reduce an overly convex nasal bone, and for assisting with repositioning of the very crooked nose.

These osteotomies are done after the medial and before the lateral.

A 3 or 4 mm straight osteotome is positioned at the caudal aspect of the nasal bone, about halfway between the medial and the lateral osteotomy. The bone cut is advanced cephalically in a straight line, to meet the fading oblique medial osteotomy.
Lateral Osteotomies

- To help minimize potential infraorbital swelling and bruising, lateral osteotomies are generally reserved for one of the final maneuvers in rhinoplasty, prior to any final adjustments and application of splints and dressings.
- Again, several kinds of osteotomes (straight, curved, guarded, or nonguarded, 2–6 mm) are available, with the ultimate choice being according to surgeon preference. As with medial osteotomies, narrower osteotomes create less tissue trauma in lateral osteotomies but require more experience to use effectively.
- Lateral osteotomies are performed through incisions at the lateral pyriform aperture, just above the attachment of the inferior turbinate to the lateral nasal wall. It can be helpful to elevate the periosteum and soft tissue along the proposed path of the lateral bone cut prior to actually executing the osteotomy to help minimize bleeding. This is done with a narrow periosteal elevator through the incision at the pyriform.
- The osteotome is firmly sited at the lateral pyriform aperture. Using the mallet, the osteotome is initially directed laterally (as though directed toward the lateral canthus of the eye) to engage the bone of the maxilla. From here it is advanced cephalically, taking care to stay low in the nasofacial groove so as to avoid a step deformity along the lateral nasal wall. If a guarded osteotome is used, the surgeon can use his or her nondominant hand to palpate the guard on the lateral edge of the osteotome through the overlying soft tissues, to precisely follow the position of the osteotome. At about the level of the infraorbital rim, the surgeon begins to curve the osteotome slightly up the lateral nasal wall to intersect with the medial oblique osteotomy at about the level of the medial canthus. At this point, the osteotome can be rotated medially to complete the fracture of the lateral nasal wall and medialize and narrow the nasal bones.
- Put firm pressure over the nasal bones immediately upon completion of the infracture, to stem any bleeding and control swelling. Thereafter, the nasal dorsum must be meticulously palpated and reinspected for any irregularities, which should be addressed at that time.

Nasal Tip Surgery

In this chapter, certain basics are presented to address the more common issues in nasal tip surgery: refinement of the nasal tip, rotation of the nasal tip, deprojection of the nasal tip, and increasing tip projection. Readers interested in greater detail should take recourse to some of the more comprehensive rhinoplasty texts.

Nasal Tip Refinement

- Cephalic trim  Narrowing the lobule generally will involve some volume reduction of the lateral crura of the LLC if the tip appears too bulbous. This is performed by a conservative trim of the cephalic border of the lateral crura. Restrict the cephalic trim to the more medial aspect of the lateral crus. Reduction of the more lateral aspect of the crura does little to enhance definition more centrally in the tip, and it risks alar collapse from overreduction of the supporting contribution of the...
lateral crura on the ala. Furthermore, as a rule, one should leave more of the lateral crus than is resected. Leaving behind 6 mm or more generally will be sufficient to prevent alar collapse or alar retraction.

- **Tip-suturing techniques** An additional maneuver to narrow the nasal tip is the use of transdomal (across the alar dome) and interdomal (between the two domes) sutures. This is a very effective and conservative (nondestructive) technique. A 5–0 monofilament permanent suture is placed in a horizontal mattress fashion, spanning the alar dome from a point medial to the dome, exiting lateral to the dome, and repassing back through the cartilage from lateral to medial such that the knot of the suture ends up between the two medial crura. As the mattress suture is tightened, the domal angle is narrowed, resulting in better tip definition as well as a slight increase in tip projection. Care must be exercised not to overtighten the suture to avoid an unnatural, pinched appearance to the nasal tip. A second 5–0 stitch is then placed to unite the domes from either side (the interdomal suture) to ensure that the two domes rest at the same level and to minimize the likelihood that soft tissue contraction will draw the two domes apart from one another, which may lead to asymmetry or bossae (knuckling or prominences) in the tip region.

- **Vertical dome division** In cases where there is greater bulbosity to the nasal tip, greater narrowing can be accomplished with vertical division or resection of a portion of the alar cartilages in the region of the alar dome. This technique requires great attention to detail to achieve the desired result. Depending on how one wishes to affect tip projection, vertical division of the lower lateral cartilages may be lateral to the dome (to increase tip projection) or at the dome with resection of the domal segment of the LLC (to decrease tip projection). Vertical dome division is usually done in conjunction with a cephalic trim. The cephalic trim is joined in continuity with excision of a cephalically based triangle or wedge of cartilage at the desired point of division. If tip deprojection is desired, a vertical segment of cartilage is excised at the domes, rather than a cephalically based wedge of cartilage. Generally, the excision should not be more than 2 mm lateral to the domes, and in all cases the medial crura are united with a 5–0 clear monofilament permanent suture after the excision is completed. Careful attention must be paid to trim any sharp or protruding edges of cartilage to avoid bossae or visible irregularities.

### Nasal Tip Rotation/Elevation

Many techniques are available to rotate or elevate the nasal tip. They may be used alone or in combination, depending on the nose. Some of the options include the following:

- **Shortening the caudal septum:** when overly long, the caudal septum may be shortened in a biased fashion, removing a wedge that is wider anteriorly to facilitate upward rotation of the tip lobule.
- **Dorsal reduction alone,** if significant, will also rotate the tip upward.
- **Trans- and interdomal sutures** (as described earlier)
- **Vertical dome division,** where the division is performed several millimeters lateral to the domes. When the two medial crura are suture united, the newly formed medial limb of the tip tripod is thus lengthened by “borrowing” from the lateral crura, thereby increasing tip projection and rotation.
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- Shortening the lateral crura, or resecting a segment of the lateral crura, will tend to rotate and deproject the nasal tip. This can be performed at the lateral extreme of the lateral crus or more centrally on the lateral crus. The two cut margins then can be sutured to one another using a 6–0 PDS suture. Care is taken to ensure that the excision is symmetric between the two sides.

- Advancing and resetting the medial crura anteriorly and superiorly on the caudal septum, and suture securing them into this new position with a 5–0 or 6–0 monofilament suture

Nasal Tip Deprojection

Deprojection of the nasal tip will happen naturally as tip support mechanisms are disrupted, whereas greater deprojection will often involve resection of a portion of either the medial or lateral crura. Options include the following:

- Dorsal reduction alone, which if substantial, will result in some deprojection of the nasal tip without manipulation of the LLC

- Full transfixion incision along the caudal septum, by separating the attachments of the medial crural feet to the septum, will retrodisplace the nasal tip, which can then be resecured in a new position with septocolumellar sutures.

- Shortening the feet of the medial crura, which will deproject the tip while diminishing tip rotation

- Shortening the lateral crura, which will deproject the nasal tip while increasing tip rotation

- Vertical dome division (as described earlier), with removal of an equal amount of cartilage from the medial and lateral crura anteriorly at the dome. This will often allow one to retrodisplace the nasal tip without significantly affecting tip rotation.

- Amputation of the anterior nasal spine

Increasing Tip Projection

Techniques include the following:

- Tip suturing, with interdomal and transdomal sutures, as described earlier

- Vertical dome division, dividing the lateral crura several millimeters lateral to the domes, to effectively lengthen the medial limb of the tip tripod

- Advancing and suture securing the medial crura on the caudal septum

- Tip grafting: suturing a shield-shaped graft to the existing domes, using a 6–0 PDS suture. Care must be taken to ensure that the edges of the graft are appropriately beveled and to ensure that they blend with the adjacent cartilage to minimize visibility.

- Columellar base narrowing suture, a suture used to pull the divergent feet of the two medial crura together. In so doing, there is a gathering effect at the base of the columella, which results in a small increase in columellar length and an increase in tip projection.

- Reduction of the dorsal nasal profile if necessary, which creates the illusion of a relative increase in tip projection
Cosmetic Use of Botulinum Toxin

Grant S. Gillman

Since receiving approval from the U.S. Food and Drug Administration for the treatment of glabellar rhytids, the cosmetic use of botulinum toxin A (Botox) has become perhaps the most popular nonsurgical treatment of the aging face. The safety profile is very high, and complications are few; nonetheless, there are technical considerations that must be considered in order to maintain a high degree of patient satisfaction while minimizing adverse outcomes. Although the range of applications of Botox continues to expand, this chapter will focus only on the most common cosmetic facial applications: the treatment of glabellar rhytids (frown lines), transverse forehead rhytids, lateral periorbital rhytids (crow’s-feet), and the adjustment of brow contour and position (chemical brow lift).

◆ General Considerations

Contraindications to Use of Botox

◆ Pregnant women or nursing mothers
◆ History of other neuromuscular diseases (multiple sclerosis, Eaton-Lambert syndrome, myasthenia gravis)
◆ Known hypersensitivity to Botox
◆ Human albumin allergy

Drug Interactions

◆ Drugs that may potentiate the effect of Botox include aminoglycosides, cyclosporine, neuromuscular blockers, d-penicillamine, quinidine, magnesium sulfate, and lincosamide.
◆ Aminoquinolines (chloroquine, hydroxychloroquine) can inhibit the activity of Botox.
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**Botox Reconstitution**

- Reconstitution should be carried out with preservative-free saline.
- Higher concentrations will result in injections of a lesser volume, which minimize the risk of inadvertent diffusion to muscles adjacent to the treatment area.
- Botox is supplied in 100 unit treatment vials. Dilution with 2 cc of saline will yield 5 units of Botox per 0.1 cc. Dilution with 2.5 cc of saline with yield 4 units per 0.1 cc. In practical terms, this facilitates easy injection of either 5.0 and 2.5 units, or 4 and 2 units, respectively—doses frequently used in facial cosmetics.
- Once reconstituted, Botox can be refrigerated. The manufacturer recommends use within 4 hours of reconstitution, although many have found Botox to retain potency beyond that time period.

**Guidelines for Use of Botox**

- Botox will be more effective in effacing dynamic rhytids (wrinkles apparent during expressive motion) and less so for deeper rhytids that persist at rest.
- A 30-gauge needle on a 1 cc syringe is used for injections.
- Duration of effect is generally 3 to 4 months.
- Maintain a diagrammatic record to help individualize or “fine-tune” treatment for best results.

**Treatment of Glabellar Rhytids (Frown Lines)**

- These include the vertical glabellar lines from corrugator superciliï contraction and the transverse line at the nasion caused by procerus contraction.
- The procerus is injected with 4 or 5 units at the intersection of two lines, each extending from the medial brow to the opposite medial canthus.
- The corrugator is injected by grasping the muscle between the thumb and forefinger of one hand while injecting with the other. Injections should remain at or above a line drawn horizontally through the level of the midbrow and medial to the midpupillary line. Serial injections perpendicular to the muscle may be used, or a threading technique may be used, where the needle is passed into and parallel to the muscle’s entire length, and the Botox is deposited at several points in the muscle as the needle is withdrawn. A total of 5 to 10 units is typically required for each corrugator.
- Corrugator injections must always be above the level of the superior orbital rim to minimize the risk of diffusion into the levator palpebrae muscle, which could cause a transient eyelid ptosis.

**Treatment of Transverse Forehead Rhytids**

- Transverse forehead lines result from the action of the underlying paired frontalis muscles. Isolated injection and paralysis of the frontalis muscles may result in brow ptosis from unopposed action of the brow depressors (procerus, corrugator superciliï, orbicularis oculi, depressor superciliï). This is more likely in patients
with very strong, dynamic brow depressors and in those patients who already have a low-set brow. Those at greater risk should consider simultaneous injection of the active brow depressors, particularly in the glabellar region (corrugator, procerus). Risk of brow ptosis can also be minimized by keeping injections 1.5 to 2.0 cm above the level of the brow.

- A serial injection technique is used, each approximately 1.5 to 2.0 cm apart from one another, following the transverse rhytids. Generally, two levels of injections, one above the other, are needed at each part of the forehead as one moves across.
- One or two units are used per injection site, for a total of 10 to 20 units for the entire forehead. Injections need only be as deep as the muscle, which lies just deep to the skin.

◆ **Treatment of Lateral Periorbital Rhytids (Crow’s Feet)**

- Lateral periorbital rhytids result from contraction of the underlying lateral orbicularis oculi muscle.
- Treatment is not recommended in those with preexisting ptosis of the upper eyelid, lagophthalmos, or facial weakness.
- Have the patient smile or squint to best identify the area in need of treatment.
- The muscle is very thin and superficial in location. Subdermal injection is sufficiently deep and will help avoid bruising at the injection site.
- Always remain at least 1 cm lateral to the lateral canthus and outside the lateral orbital rim to avoid diffusion into the levator palpebrae superioris (which could cause transient lid ptosis) or the lateral rectus (which could cause transient diplopia or strabismus). Unless elevation of the lateral brow is desired, stay 1 cm below the tail of the brow.
- Multiple serial injections (usually 2–4) perpendicular to the muscle just outside the orbital rim are used. A total of 4 to 15 units may be required, depending on the depth and distribution of the lines and the activity of the underlying orbicularis oculi.

◆ **Adjustment of Brow Position and Contour (the “Chemical Brow Lift”)**

- The targeted muscles—the brow depressors—include the lateral orbicularis oculi, the corrugator supercilii, the procerus, and the depressor supercilii (the medial portion of the orbicularis oculi, which lies beneath the medial head of the brow).
- Elevation of the entire brow requires treatment of both the medial and lateral brow depressors. Frequently, however, elevation of only one end of the brow or the other may be desired (more commonly lateral).
- Medial brow elevation involves treatment of the corrugators and procerus (as previously outlined) and the depressor supercilii, which is injected with 2 to 4 units just inferior and just lateral to the medial head of the brow. Care must be taken to
remain outside the orbital rim and superficial to avoid unwanted diffusion into adjacent muscles.

◆ Lateral brow elevation requires a subdermal injection of the orbicularis oculi just inferior to the lateral brow and above the orbital rim, lateral to the high point of the brow. One to three injections may be required, a total of 4 to 10 units. Avoid injection of the frontalis above the lateral brow to benefit maximally. The effect of the lateral brow elevation is best appreciated as diminished hooding of the lateral upper lid.

◆ Complications are best avoided by using a high concentration–low volume injection, immediately subdermal and remaining outside the bony orbital rim.
Cleft Lip and Palate Repair

Anil Gungor

◆ Cleft Lip Repair

◆ The surgical/aesthetic success of cleft lip repair is dependent on:
  ◦ Extent of deficiencies of bone, cartilage, and soft tissue
  ◦ Surgical skill and technique
  ◦ Attention to details, such as racial characteristics, biology of scar formation, parent education, and cooperation in postoperative care

◆ Simultaneous repair of the cleft lip and cleft nasal deformity grant the best results. Future nasal reconstruction may not be necessary with simultaneous repair.

Preoperative Considerations

◆ Preoperative evaluation includes determination of:
  ◦ Width of cleft and deficient lip elements
  ◦ Extent of nasal deformity
  ◦ Columellar dimensions
  ◦ Premaxillary protrusion

◆ Lip repair should be undertaken at 10 weeks of age, in a child of at least 10 lbs, with a minimum hemoglobin level of 10 g/dL. Airway obstruction, comorbid conditions, and genetic evaluation should be resolved prior to surgery.

◆ The use of presurgical orthopaedics (PSO) (combined nasoalveolar molding with maxillary and premaxillary manipulation) in clefts with severe asymmetry and/or severe protrusion of the premaxilla and short columella will improve cosmetic outcome and reduce risk of postoperative wound dehiscence.
Surgical Technique

- Millard's original description (1976) of the rotation–advancement technique provides consistently pleasant results for unilateral clefts. The goals of surgery are to:
  - Match the scar of repair with the philtral column on the noncleft side
  - Create three-dimensional symmetry of the Cupid's bow on the cleft side
  - Match the white roll on the vermilion-cutaneous border and the red line (wet vermilion to dry vermilion) on the mucosal lip (Fig. 41–1A).

- All landmarks are carefully marked after measurements with surgical calipers using operating loupes. Marking starts with the identification of (1) the low point (midline) and the peak (2) of the noncleft side (NCS) Cupid's bow. The distance between these two points is used to determine the position of the peak of the Cupid's bow on the cleft side (CS) (3). The alar base on the NCS (4), the columellar base (5), and the commissures (6) and (7) are marked freehand. The lateral peak of the Cupid's bow (8) is marked by taking the distance from the CS commissure and the width of the vermilion into account. The combined vertical height of the wet and dry vermilion at (8) should match that of the vertical height of the vermilion at (3) (r and r'). Therefore, (8) can be placed within 1 to 2 mm of the measured distance (matching the distance between (2) and (6)) from the commissure, to match the vermilion in height. A close match of the required vermilion height is necessary. The alignment of the red line and additional vermilion height is obtained by drawing a laterally based triangular vermilion flap (VF) on the CS (Fig. 41–1B).

- The tip of the advancement flap (9) is marked so that the distance between (8) and (9) matches the distance between (2) and (5) (Fig. 41–1A). Avoid discolored, thin skin with increased vascular patterns when designing the flap. The slightest difference in color here will be highly visible against the contrast provided by the NCS lip and columellar skin.

- The nasal tip (projection) and columella are the slowest growing elements. These features can be constructed of normal size or of slightly larger than normal size.

- The rotation incision is followed by a very small (<1 mm) releasing cut made high in the lip in a near-perpendicular angle to the rotation incision (Fig. 41–1B). This should allow the NCS to drop down without tension, creating a symmetrical prolabium and minimal transgression of the upper philtral column. Do not extend the back cut to the columella or across the philtrum.

- The orbicularis oris is dissected from the skin along the rotation and advancement flaps. The extent of the dissection should not exceed 1 to –2 mm on the advancement flap and should not extend over the philtral dimple (midline) on the rotation flap (Fig. 41–1C). The dissection is performed to facilitate layered closure and should not be used as an aid for further rotation or advancement. If feasible, the muscle may be interdigitated.

- Mucosal closure is started in the sulcus and extended toward wet vermilion with 4–0 chromic gut. This repair should leave no raw area. The depth of the gingivalabial sulcus is dependent on this repair.

- Repair of the orbicularis oris muscle can be initiated at the free border of the lip moving toward the nose, with eversion (horizontal mattress sutures) of the muscle
Figure 41–1 (A) All landmarks are carefully marked with a fine-tip surgical marker or gentian violet. The red line separates wet vermilion from dry vermilion. Marks on the vermilion-cutaneous border are made on the white line. See text for explanation of numbered and lettered points. (B) Lateral-based vermilion flap (VF) is designed to have its lower limb in the same line as the red line. Its tip is sutured into the cut made in the noncleft side (NCS) red line. The tip of the advancement flap is freed from the nose by a circumalar incision of variable length as needed. (C) The lower lateral cartilage (LLC) is dissected free from the skin up to the dome and across if necessary. The circumalar incision is adequate for this dissection. (D) The LLC is suspended to
along the planned philtral ridge. This maneuver produces an elevation that simulates the philtral ridge. If the muscle is approximated appropriately along the inferior border, whistle deformity can be avoided. The adequacy of the rotation is checked after each suture by comparing the symmetry and the level of the Cupid’s bow to the NCS.

- The lower lateral cartilage (LLC) is dissected free from its skin (including between medial crura and dome) (Fig. 41–1C) and suspended to the ipsilateral upper lateral cartilage (ULC) with a looping suture (Fig. 41–1D). If necessary, interdomal sutures and suspension sutures (Fig. 41–1E) are used to sculpt the nasal tip. This requires an extended dissection. Do not dissect the LLC from the mucosa or vestibular skin because severe scarring and subsequent nasal stenosis may occur.

- The dislocated nasal septum is released, transposed, and secured through the membranous septal incision (Fig. 41–1D).

- The nasal ala is repositioned to address symmetry in all three dimensions (Fig. 41–1E). In most complete unilateral clefts, the alar base has to be dissociated from the lateral lip and pyriform aperture by extending the circumalar incision (alotomy) (Fig. 41–1C), allowing these elements to move independently.

- The advancement flap will be advanced more than the ala (Fig. 41–1E). The muscular tip of the advancement flap is anchored to the membranous septum.

- The lip is dissected from the face of the maxilla in a supraperiosteal plane with care to avoid the infraorbital nerve. The alar base is secured to the orbicularis muscle to prevent “nostril snarl,” an elevation of the ala nasi with smiling due to unopposed action of superior levator labii. Symmetrical placement of the ala can be achieved by excising skin along the nasolabial cut.

- Intranasal webbing of the LLC after repositioning is corrected with two or three suspension sutures in the nasal alar crease. A lenticular mucosal excision at the intercartilaginous line may be necessary to control large webs.

- The nostril is stented for 2 to 4 weeks with silicone nostril retainers (Porex Surgical, Inc., Newnan, Georgia) to prevent distortion in the nostril shape (Fig. 41–1F).

- Skin is closed with 5–0 or 6–0 nylon. The high point of the Cupid’s bow and continuity of the white roll are formed with a 6–0 suture placed on the white roll. This suture should be at the same level with the high point of the Cupid’s bow on the nonleft side. If the rotation is insufficient, a triangular white roll flap is designed to drop the Cupid’s high point.

◆ Cleft Palate Repair

- Modern palatoplasty aims to assemble an intact and functional palate for development of normal speech and closure of the oronasal aperture. Best speech results
Figure 41–2 (A) The Furlow method uses the cleft mucosal edges, the hamuli, the hard palate, and the torus tubarius as landmarks to design three-dimensional flaps. Posterior-based flaps always have the muscle, and adequate mobilization is achieved by complete dissection of Veau’s muscle from its hard palate attachments. Lateral relaxing incisions and entry into the space of Ernst are unnecessary. (B) Incisions are placed on the palatal mucoperiosteum, and extension into the alveolus is avoided. The medial cleft mucosal border is carefully used to gain width on the nasal mucoperiosteal flap by designing a mucosal cuff made of oral mucoperiosteum.
are obtained when surgery is performed between 9 and 18 months of age, prior to the initial development of speech.

◆ The type of cleft, length of palate, width of cleft, and adequacy of palatal shelves usually dictate the timing and the type of repair. A cleft of the soft palate only may be repaired at 6 to 9 months of age. A bilateral cleft is usually repaired at 12 to 18 months of age. Unusually wide clefts require longer periods for the palatal shelves to attain adequate size. Severe airway obstruction may require delay in plans for repair.

◆ Adequate mobilization is necessary for a tension-free closure (Fig. 41–2A–E). Intravelar veloplasty (IVV) is performed for the correct alignment of the muscular sling in all types of palatoplasty (Fig. 41–2D) with the exception of the Furlow method (Fig. 41–2A). All muscle attachments (Veau’s muscle, levator, and palatopharyngeus, also known as the cleft muscle) to the hard palate are stripped (Fig. 41–2C), and muscle is dissected free of both the nasal and oral mucosa in the soft palate.

◆ Atraumatic technique with layered closure is the key to prevent fistula formation. Vicryl is the author’s preferred suture (atraumatic, 3–0 to 5–0) for all layers of closure.

◆ The neurovascular bundle is always preserved (Fig. 41–2C,D). Gentle dissection around the bundle's mucoperiosteal cone will adequately release the flap medially. The space of Ernst may be entered for further mobilization of the flaps when necessary. Infra-cuture of the hamulus and gentle stripping of the levator tendon are adequate for the medial mobilization of the flaps. Transection of the hamulus is not necessary.

◆ Flap design at the hard palate should leave an adequate cuff of mucosa that can be inverted to close the nasal mucosal layer without tension (Fig. 41–2B,D). The wider the cleft, the wider the strip of mucoperiosteum that must be left on the medial edge of the cleft.

◆ Furlow palatoplasty and V to Y push-back palatoplasty techniques add ~1 cm in length to the repaired palate. These techniques are used in incomplete clefts of the secondary palate (Robin type) where hard palatal involvement is limited (Fig. 41–2D).

◆ Furlow palatoplasty can be combined with the two-flap palatoplasty for complete clefts with a short palate. Two-flap palatoplasty with IVV is an appropriate choice in palates with adequate length.

◆ A vomer flap is used in wide clefts to ensure tension-free closure.

◆ The oral mucoperiosteal closure brings the flaps (two-flap, V–Y) together with horizontal mattress sutures. This sturdy layer is also used to “tack” the flaps down

(C) Dissection is submucoperiosteal and blunt. The muscle is dissected sharply. The mucoperiosteal cone around the neurovascular bundle is scored and stretched for medial mobilization of the flaps. (D) Dissected muscles are retropositioned and sutured onto each other end to end. Nasal mucoperiosteum is closed with interrupted sutures, tied on the nasal side. (E) Simple interrupted sutures bring the flaps together, and these are attached to the nasal mucoperiosteum by either tacking sutures or vertical mattress sutures (not shown). Avitene (microfibrillar collagen) promotes hemostasis and mucosalization.
to the nasal mucosal layer at around midpoint on the hard palate cleft with a co-
apting suture. The tip is also sutured to the alveolar mucosal flap, thus stabilizing the flap and decreasing the potential space (Fig. 41–2E).

• Exposed bone in the lateral gap is filled with microfibrillar collagen (Avitene®) rolled into small spheres (Fig. 41–2E). Care is taken to avoid undermining the flap. The spheres further stabilize the flap and are hemostatic. When filled with microfibrillar collagen, mucosal cover of the lateral gaps is complete within 2 weeks.

◆ Postoperative Care for Lip and Palate Repair

• Children are kept overnight with a tongue stitch in place. The tongue stitch is used to apply traction to the tongue after extubation and prevent airway compromise. The staff should be instructed to not use an oral airway stent, but instead to take advantage of the tongue stitch when necessary.
• Antibiotic ointment is applied to the incisions (lip) several times through the day.
• Arm restraints are used for up to 2 weeks. Children are kept sleeping in their car seats after lip repair for 1 week.
• Bottle feeding is prohibited for 2 weeks. A cup, sippy cup, spoon, or syringe may be used.
• Lip sutures are removed on postoperative day 7 in the office or in the operating room.

Reference

Digital Imaging and Archiving

George C. Yang

◆ The Role of Digital Imaging and Archiving in Otolaryngology

◆ Photodocumentation in the clinic
  ◦ Facial, oral cavity, neck lesions
  ◦ Preoperative facial analysis
  ◦ Sinonasal, otologic, or laryngologic findings
  ◦ Radiologic findings

◆ Instant review of images for preoperative counseling
◆ Intraoperative digital image capture and digital video recording
◆ Postoperative documentation
◆ Self-evaluation of surgical technique
◆ PowerPoint™ presentations
◆ Digital images inserted in referral letters

◆ Components of Digital Imaging and Archiving

Digital Camera

The following factors may influence camera selection.

Uses of the Digital Camera

◆ Portrait photography, versatility with endoscopic adapters, intraoral photography, and intraoperative photography.
The body type of the camera dictates point-and-shoot versus single lens reflex (SLR) with interchangeable SLR lenses and shoe adapter for external flashes.

Resolution

◆ Should be a minimum of 1.3 to 8 megapixels.
◆ 1.3 megapixels is adequate for publication quality as well as presentation quality for PowerPoint.
◆ To enlarge a photograph to a 5×7 inch print, a minimum of 2 megapixels is needed; for an 8×10 inch print, 3 megapixels is needed. A 5 megapixel image can be enlarged to 11×17 without graininess.

Lens Type

◆ Quality lenses help to increase the quality of photographs in conjunction with the resolution.

Zoom Capabilities

◆ Digital cameras have two types of zoom: digital and optical.
◆ Optical zoom allows for enlargement of subjects without any loss of resolution.
◆ Digital zoom requires lowering of resolution to enlarge the subject.
◆ The less expensive cameras may not have optical zoom.

Battery Type, Memory Card Type, and Price

◆ Less important criteria are the batteries, memory type, and price. Compact flash, smart media, secure digital, memory stick, or XD picture card (Fujifilm U.S.A., Inc.) have different costs for the same amount of memory. The battery type directly affects cost and flexibility.
◆ Digital cameras expend battery life extremely quickly, so it is important to have a backup power source to ensure continuous use of the cameras.
◆ Cameras that use AA nickel metal hydride batteries have a unique advantage over cameras that use lithium ion batteries because the AA nickel metal hydride batteries are cheaper to replace.
◆ Currently, it costs about $35 to $45 for a single lithium ion battery alone versus $15 to $30 for four AA batteries with charger. Therefore, multiple sets of AA batteries can be purchased and charging while the other sets are in use. In an emergency, alkaline AA batteries can be used; however, these batteries will last for only a handful of pictures before running out of power.

Scanners

◆ Many otolaryngologists already have a collection of photographic prints, 35 mm slides, or 35 mm film negatives, and thus they may be reluctant to invest in a
digital camera or digital video/image capture system. Their media collection can be converted to digital files for archiving by using either a flatbed scanner or slide scanner. However, scanning can be very tedious and time consuming. It may be more cost and time effective to have the medical media department or third party convert the photographs, slides, film, and videotapes into digital images and video without investing in more hardware (i.e., scanners).

Selection Criteria

◆ Flatbed versus Slide Scanner
◆ When selecting a scanner, the type of media to be scanned will determine whether to purchase a flatbed scanner and/or a film/slide scanner. A flatbed scanner is primarily used for prints, whereas a slide scanner is suitable for 35 mm slides or negatives. High-end flatbed scanners have the ability to scan slides or film. However, if an entire slide collection is to be scanned, then a dedicated slide/film scanner would do a better job.

◆ Resolution
◆ Most flatbed scanners have a true hardware resolution of at least 300 × 300 dots per inch (dpi). Film scanners can scan to a resolution of over 3000 dpi. Memory cost can be quite high when scanning film because a slide/film scanner can acquire a very high resolution digital image.

◆ Bit Depth
◆ Bit depth, also called color depth, refers to the number of colors that the scanner is capable of reproducing. The current scanners on the market support 24 bits, which is required to create a true standard color. There is not a noticeable difference in quality between 24 bit and higher bit scanners with 30 and 36 bit.

Computer Hardware and Software

◆ The computer hardware for archiving digital images becomes even more important than in 35 mm photography, because it also becomes the only way to view and access the digital images. Although accessing the images is faster and easier, there are long-term issues to keep in mind.

Selection Criteria

◆ Hardware
◆ Large hard drive
◆ Fast processor
◆ USB port ready
◆ Digital media reader
◆ CD or DVD recordable drive
◆ Backup hard drive
Software

Operating system

Medical archiving databases

The features in a personal computer should include a large hard drive, adequate internal memory, fast processor, a USB port, a digital media reader, CD or DVD recordable drive, and backup hard drive.

Large Hard Drive

Most digital photographs can range from 300 kilobytes (KB) to 1 to 2 megabytes (MB) per image, depending on the resolution (number of megapixels) at which the photo was taken. Therefore, these images can quickly fill a hard drive. A minimum of 20 gigabytes (GB) ranging to a current maximum of 300 GB is preferred.

Another option is to purchase an external hard drive of similar size that connects to the personal computer (PC) through a firewire or USB 2.0 port. This allows access to the hard drive at comparable speeds to an internal hard drive. Another method would be to use the external hard drive to back up the existing hard drive.

Internal RAM Memory

Images and video require more processing power and memory than word processing or spreadsheet programs. A minimum of 256 MB to 1 GB of memory would be recommended, especially if any video archiving or editing were involved.

Fast Processors and Video Cards

Intel Pentium 4, AMD Athalon, or Mac G5 processors are recommended. Although a slower processor can be chosen, the processors can become outdated if not obsolete within a few years. Therefore, the fastest affordable processor should be chosen at the time of purchase to allow the computer to have maximal usage over the years.

Software

The current PC/Mac operating systems (Windows, Mac OS) allow for archiving in a very basic form using files and folders, similar to the current physical form. However, because these files are digital, current operating systems allow for sorting of files by name, file type, size, date, and time, as well as searching for files using the same criteria.

There are many medical software companies with different database programs that will archive digital images and video as well as perform electronic medical record keeping, demographics, and billing. Unfortunately, currently there is no standard, and depending on the subspecialty, some software is better geared for laryngology, swallowing, or facial plastic surgery.
Chapter 42  Digital Imaging and Archiving

◆ Digital Imaging Systems

◆ The subspecialties in otolaryngology that benefit most from digital imaging systems are laryngology, swallowing, sinus surgery, and otology. These specialties have disease processes that have been traditionally photodocumented or videorecorded.

◆ The major medical manufacturers of endoscopic video cameras, scopes, and instruments have incorporated digital imaging into the systems that they are currently marketing. The early charge-coupled device (CCD) camera sends an analog video signal, which has 200 to 300 horizontal lines of resolution. This low-resolution analog video or image can be recorded by digital video capture systems. The digital capture systems can record a DVD quality image of 640 × 480 pixels of resolution. Thus the analog video signal becomes the limiting factor.

◆ The similarities in the latest digital imaging systems attempt to digitally capture a DVD quality video or image at the level of the CCD camera, which is saved directly to the hard disk. These integrated systems have a Windows-based operating system with a built-in central processing unit (CPU), which acts as a dedicated digital video recorder. After the case is recorded on the hard disk, it can be permanently archived to a CD-R/RW or DVD-R/RW, depending on the system.

◆ The following are examples of digital imaging systems (DIS) and their usage (available DIS: subspecialty/usage)

◇ Kay: laryngology/clinic (Kay Pentax, Lincoln Park, NJ)
◇ Pentax: swallowing/clinic (Pentax Imaging Company, Golden, CO)
◇ Storz: sinus, laryngology, otology/ intraoperative (Bausch & Lomb, San Dimas, CA)
◇ Stryker: sinus, laryngology, otology/ intraoperative (Stryker, Karamazoo, MI)

◆ Pearls and Pitfalls

How to Take Digital Photographs

◆ The keys to taking good photographs and video clips are the same whether analog or digital.

◆ Intraoperative photographs of a surgical field should be taken after the operative site has been cleaned and draped with clean towels, with the overhead lights turned away and with the flash on.

◆ It is important to be cognizant of the distance of the camera to the subject being photographed, because if the camera is too close, the macro feature of the camera will need to be activated to allow the camera to focus. If the macro is not activated when the camera is within 1 to 2 feet of the subject, all the photographs will be out of focus.

How to Use a Scanner

◆ In general, scanning color photographs is recommended at 150 to 300 dpi. To scan a photograph at any higher resolution than 300 dpi would only enhance the graininess of the photographic print. Therefore, scanning film often gives better results.
than scanning prints. One obvious reason is because the film is the original image instead of a second-generation copy. This means that film contains much greater detail than is possible in prints. Film also has much greater dynamic range (contrast) than prints. These differences are very real, and critical commercial work normally scans film, usually slides.

- Film scanners have the capability to scan to a resolution of over 3000 dpi. However, it would be an overkill and waste of memory if every slide or film image is scanned to that resolution.
- As a general guideline, the scan resolution for the film scanner should be set at 1000 to 1500 dpi to get a resulting image of ~1280 × 960 pixels (~1 megapixel), or ~1600 × 1200 pixels (~2 megapixels).
- To enlarge a photograph to a 4 × 6 inch print, a minimum of 1.3 megapixels is needed; for a 5 × 7 inch print, a minimum of 2 megapixels is needed; for an 8 × 10 inch print, 3 megapixels is needed. A 5 megapixel image can be enlarged to an 11 × 17 inch print without graininess.
- Dust and scratches are greater problems when scanning film because film is very fragile, and scratches and oily fingerprints are a main risk and concern. These imperfections will also be scanned into the image with magnification; therefore, be sure to handle the film carefully, and clean the surface with an aerosol can air compressor to remove dust without rubbing the film surface before loading the film into the scanner.

How to Archive

- The main issues with archiving are image type, image/file size, organization, retrieval, and backup of data.
- TIFF (or Tag Image File Format) is the format of choice for archiving important images; it is the most universal and most widely supported format across all platforms (Mac, Windows, Unix). Data up to 48 bits are supported.
- The JPEG (Joint Photographic Experts Group) format also has its important utility, as it is able to create files that are small, often compressed by 90%, or to only 0.10 the size of the original data, which is very good when modems are involved.

Image File Formats: Which to Use?

- JPEG format is great for many purposes, but archiving maximum quality is not one of them. Because JPEG files are much smaller, they are more suitable for nonarchival purposes, such as photos for read-only e-mail and Web page use, when small file size may be more important than maximum quality. This is because its compression efficiency also causes some image quality to be lost when the JPEG data are compressed and saved. The lost quality or data, although varying in degree, can never be recovered because JPEG is designed to give very small files without the requirement for full recoverability. The quality of a JPEG file further deteriorates after each compression or save.
- For the best image with archive quality, TIFF is recommended. However, one of the disadvantages is that TIFF files for photo images are generally large. Uncompressed
TIFF files are about the same size in terms of bytes as the image size in memory. Regardless of the novice view, the large memory size is not a disadvantage because TIFF includes lots of detail, crucial for those master archive copies. In addition, TIFF stores maximum image quality in a fully recoverable format. Because it costs around $200 to buy a 60 GB disk and 512 MB of memory, it is relatively easy to plan for and deal with the size issue.

- The best way to reduce file size is to reduce resolution to a useful amount. However, if there is ever a need to work up near 300 dpi with color images, a huge amount of memory is needed because a 300 dpi 8.5 × 11 inch color image requires 25 MB.

- With the sophistication of the current operating systems with Windows XP and Mac OS, the digital images for a single case can be stored in a folder labeled with the patient's name. Current operating systems allow for thumbnail images to be viewed within the folder without actually opening each digital image into a program such as Adobe Photoshop. These files can be organized alphabetically or by the date the folder was created. If these images are mainly for use in presentation and not for an electronic medical record, then the patient folders can be further separated into different categories of interest depending on problem or disease process.

- One useful tip is to partition the hard disk drive into an area the size of the optical disk drive recorder that the computer has (e.g., 650 MB for a CD-R or 4.4 GB for a DVD-R). When this area of the hard disk becomes full over time, the entire archive can be permanently recorded on a single optical disk, which can be labeled for that time period. All of these images need to be backed up each time new images are added, using another hard drive of equal or greater size, and/or a tape drive, which is becoming less commonly used.
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