Atlas of Paranasal Sinus Surgery

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Preface

Atlas of Paranasal Sinus Surgery has been written with the purpose of providing a succinct comprehensive atlas of sinus anatomy and surgical techniques. It is hoped that herein the surgeon can learn or refresh his or her memory about sinus surgery to help optimize patient care.

During the writing of this book, it quickly became evident that paranasal sinus surgery is markedly different from what was practiced just a decade ago. The two editions of *The Paranasal Sinuses: Anatomy and Surgical Technique* were manifestations of Dr Frank Ritter's keen interest and expertise in paranasal sinus surgery. The book was very warmly received.

Since the first edition of *The Paranasal Sinuses: Anatomy and Surgical Technique* was published, many surgical techniques have been refined. Additionally, completely new procedures have come into being. Indeed, the entire field of endoscopic paranasal sinus surgery has emerged and matured. Concurrently, understanding of sinus surgical anatomy has taken on new perspectives. Also, other specialties which interact closely with Otolaryngology as part of the head and neck "team" are involved in incorporating sinus knowledge into their own specialties. Thus, radiologist, ophthalmologists, oral surgeons and infectious disease specialists are integrating these techniques into their patient diagnostic and treatment regimes. Thus, the challenge of Frank and my collaboration was to combine an eclectic harvest of classical anatomic and surgical understanding with newer refinements and wholly new skills developed over the last decade.

Daily, a renaissance of sinus care progresses in which we all participate.

The authors wish the readers diagnostic and treatment excellence and many happy patients!

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Part One

Embryology, Anatomic Considerations, Clinical Correlations

1. Introduction - The Paranasal Sinuses

The paranasal sinuses are a series of pneumatic cavities that surround the nasal chamber and lie immediately adjacent to the orbit and to the dura of the anterior cranial fossa. They originate during early fetal life or childhood, and their pneumatic expansion continues until early adulthood. Because of their origin and growth from the nasal chamber, they share characteristics of this structure, such as its lining membrane and its diseases. The orbit, brain, and vital neural and vascular structures, which are adjacent to the paranasal sinuses, may develop serious complications from sinus diseases or from surgery performed on these cavities.

Histology

The internal lining membrane of the sinuses is a thin mucoperiosteum. The mucosal portion contains cilia and mucous glands, although these are not as numerous as those located in the nasal mucosa. The mucosa is covered with a blanket of mucus that is propelled by the cilia toward the natural ostium of the sinus. The cilia and mucus are necessary for drainage of the sinus, since only the frontal and some of the ethmoidal sinuses have a dependent ostium, at least when the head is erect. The mucosa has a great ability to regenerate if it is destroyed either by infection, injury, chemicals, or surgery. Regenerated mucosa, however, is less well-endowed with cilia and mucous glands and is scarred, both factors that lessen its resistance to future infections. Additionally, disruption of the normal fluid-gel layers of the mucous blanket will give rise to stasis and possible expansion of pathology. For these reasons, not only in surgery but also in examining patients with sinus diseases, the knowledgeable physician considers the microscopic anatomy of the sinus mucosa, with its need for mucus and moisture, as it relates to the behavior of viruses, bacteria, chemicals, neoplastic cells, or postoperative changes, whichever are involved.

Functions

The paranasal sinuses have no discernible function in humans. Skillern has speculated that they (1) are rudimentary in humans but of olfactory use in animals; (2) give some assistance in olfactory function by evenly distributing the inspired air in the olfactory region; (3) lighten the skull for better balance; (4) are resonators for voice; and (5) are areas for the production of mucus to moisten the nasal chambers and the inspired air. At present these remain only theories.

Pathology

The mucosa of these cavities is susceptible to inflammatory, neoplastic, metabolic, and traumatic changes. Inflammatory and metabolic or allergic changes cause hyperplasia and hypertrophy of the mucosa, whereas neoplasms destroy the mucosa and surrounding bone.

Most blunt trauma causes a temporary disjunction of the mucosal lining at the site of the injury; unless the ostium of the sinus is damaged or the trauma is severe, the sinus often recovers without sequelae. In contrast, on other occasions the trauma may so injure the mucosa that healing produces a linear strip of scar devoid of mucous glands and cilia. Mucus then secreted by the mucosa distal to the scarred ostium will be sequestrated and become secondarily infected. These changes may take years to produce clinical manifestations, such as a mucocele or an osteomyelitis.

Methods of Examination

Through speculum rhinoscopy the physician can recognize an allergic reaction or infection of the nasal mucosa; using extrapolation of the effect, the physician can then speculate on what is present within the sinus lumen. Transillumination is of more help, but this is restricted to the maxillary and frontal sinuses, and it must be understood that any cavities that are dark on transillumination are under suspicion until radiographs are obtained. Endoscopic (both telescopic and fiberoptic) visualization as an office diagnostic procedure is considerably more revealing in many cases. Close-up views of ostia and pathology are possible. Although radiographs in the routine views (Waters, Caldwell, submental-vertex and lateral) are of great diagnostic help, computed tomography using "bone windows" best delineates sinus anatomy and pathology. Histologic examination of the mucosa and its contents may also be of diagnostic assistance.

"Sinus"

The otorhinolaryngologist is very much aware of the person whose complaint is "sinus". This complaint is usually synonymous with a stuffy nose and symptoms of allergy, chronic infection, or nasal septal problems. However, it may mean physiologic postnasal "drip" or headaches, with a "drawing" feeling in the cheeks or above the eyes. Rhinoscopy, x-ray studies, and microscopic examination of the nasal discharge and allergy testing may fail to reveal an etiologic factor. Often, some of these patients have undergone repeated trials of antibiotics, hormones, vitamins, antihistamines and decongestants, Proetz displacement therapy, desensitization, topical anesthesia, and surgery; for the most part nothin has been effective. Thus, the experienced clinician is usually frank about the condition. Not all "sinus" can be effectively treated by an otolaryngologist.

2. The Maxillary Sinus (Antrum of Highmore)

Embryology

The maxillary sinus is the first sinus to develop. At approximately the 70th day of gestation, after each nasal fossa and its turbinates are already established, a small ridge develops superior to the inferior turbinate and projects medially into the middle meatus. This is the rudimentary uncinate ridge or process. Shortly thereafter, just posterior and superior to this ridge in the middle meatus, a mucosal bud slowly burrows laterally into the maxilla. The evagination is located in the central part of the middle meatus, termed the infundibulum. From this primordial dimple, the evagination expands so that a cavity measuring 7x4x4 mm is present in the maxilla at term. The cavity is longer in the anteroposterior dimension, and its height and width are about equal. After birth, as the facial structures grow anteroinferiorly away from the skull, the maxillary sinus also expands in this same direction. Its rate of growth is estimated to be 2 mm vertically and 3 mm anteroposteriorly each year. With progressive growth, by the age of 12 years the floor of the sinus has expanded to such a degree that it lies on a horizontal level with the floor of the nasal chamber.

Expansion of the maxillary sinus is intimately related to dentition. As a tooth erupts, the space vacated by it becomes pneumatized by the expanding sinus lumen. Expansion ceases after the permanent teeth erupt. Schaeffer has determined the adult size of the maxillary sinus from measuring it in 150 skulls and noted that it averages 34 mm anteroposteriorly and is 33 mm high and 23 mm wide. In volume, it holds approximately 14.75 mL of solution.

Clinical Correlations

It is often helpful for the surgeon to recall the embryology of the maxillary sinus when entering it either for irrigation or for external surgery. Since the lumen of the sinus progressively expands in growth from above downward, the younger the patient, the more likely it is that the floor of the sinus lies above the level of the floor of the nasal chamber. Therefore, in a child, the irrigating needle has to be directed more superiorly to gain entry to the sinus lumen.

The orbital floor bulges inward (inferior) toward the maxillary sinus and does not lie on a true horizontal plane but angles downward 30 to 45° as the orbital floor passes laterally and posteriorly. It is important to be aware of these points when utilizing an instrument in the sinus during irrigation and in curettement during the Caldwell-Luc procedure, so as to avoid penetration of the orbital floor and injury to the globe.

In the inferior part of the sinus, the relationship to the teeth varies according to the size of the sinus lumen, which in turn is dependent on the age of the patient. In the adult, the roots of the three permanent molars almost always project into the lumen, the two premolars do so occasionally, and the canines, rarely. In some instances, alveolar expansion of the sinus may be extensive, and the roots of these teeth project upward through the floor and produce sharp ridges. Sometimes these dental ridges may create narrow crevices in which granulation or polypod tissue can be trapped, making removal at surgery difficult. It is this proximity of the teeth and the sinus lumen that explains the not uncommon maxillary sinusitis of dental origin.

For the maxillary as for all the other paranasal sinuses, the ostium is always located at the site of the initial embryonic evagination from the nasal chamber. The maxillary ostium is round or oval, approximately 4 mm in diameter at the sinus end, and about 1 cm in length. It lies in the bone of the middle meatus termed the fontanelle. Sometimes on examination of a skull, one or even up to three ostia can be noted (20 to 50%). These also lie in the middle meatus, but it is difficult to explain their origin embryologically. Though unknown, the likely reason for their existence is that the mucous membrane of the fontanelle breaks down as a sequela of infection, producing the ostium. This would be analogous to otitis media producing a tympanic membrane perforation.

This membranous area is also important in efforts to irrigate the antrum via the natural ostium. Just anterior to the ostium lies the uncinate ridge, which may overlay the ostium. Van Alyea estimated that in 19% of 163 skulls he studied, this ridge was the single feature that would prevent cannulation because of its height. Therefore, when the natural ostium cannot be located, the thin membranous area of the middle meatus is penetrated for irrigation. Most natural ostium cannulas have a sharp tip to accomplish this maneuver.

Anomalies

For unknown reasons, during growth the maxillary sinus may cease development and produce a sinus lumen of less than normal size. Rarely, the sinus may not develop at all (agenesis). These conditions may be detected only by transillumination techniques during physical examination, for the maxilla does not appear grossly abnormal to inspecton or palpation. Radiographs, however, will demonstrate the partially developed sinus. In the case of agenesis, the maxilla will appear homogeneously dense on the radiograph and be similar to a sinus that appears opaque because it is filled with inflammatory disease. Differentiation of the inflammatory disorder from agenesis is difficult. One way to diagnose agenesis is to search closely for the lateral edge of the sinus lumen in a Waters' view. CT and MRI imaging are useful.

Whenever opacity of the maxilla occurs, agenesis should be borne in mind so that the patient will not undergo a surgical attempt at irrigating the sinus or instrumenting it.

3. The Ethmoidal Sinus

Embryology

The ethmoid bone is a very light, papyraceous osseous structure. Attached to each edge of the cribriform plate is a block of ethmoidal sinuses. Unilaterally, each block of sinuses is made up of a group of 3 to 15 air cells. Their formation begins during the 5-month of intrauterine life as numerous evaginations from the fetal nasal chamber into the anlage of the ethmoid bone. At first these evaginations are mere slits, but they quickly grow into a tubular form before assuming a round or globular shape at term. The expansion of each air cell is at the expense of the ethmoid bone. This, with rapid growth the cells soon abut each other. The haphazard growth of cells makes each person's ethmoid labyrinth different from the next. The expansion of these cells continues until late puberty or until the wall of the sinus strikes a layer of compact bone or another sinus. By adulthood the ethmoidal block averages 3.3x2.7x1.4 cm in size, with the longest dimension being the anteroposterior. Actually, the ethmoidal cell block or labyrinth is pyramidal in shape, being wider posteriorly (where it abuts the sphenoid bone) than anteriorly (where it contacts the lacrimal bone). Cells that reside within the ethmoid bone are termed intramural cells, whereas those whose expansion takes them into an adjacent bone such as the frontal, sphenoid, or lacrimal bone or the maxilla are called extramural. Even though growth of the cells results in air sinuses that are of different size and shape, the ostium of each sinus is at the site of the cells' initial evagination from the fetal nasal chamber. Also, regardless of the location of the ostium, the air cell is named for the bone in which it finally resides. For example, the frontal sinuses are in reality often displaced anterior ethmoidal cells.

The ostia of the ethmoidal sinuses are the smallest found in any of the paranasal sinuses, measuring 1 to 2 mm in diameter. From such a size it can be understood how these ostia become easily stenosed by edema or polypoid formation, thus causing a mucocele. As a rule, ostia of the anterior ethmoidal cells are even smaller than those of the posterior ones - the reason an anterior ethmoidal cell is the usual one involved in mucocele formation.

Anatomic Considerations

For an anatomic description, it is best to consider the ethmoidal labyrinth as a box. The top wall or roof of the ethmoidal air cell box is termed the fovea ethmoidalis. The fovea is not a flat plate of bone but undulating, because the domes of the topmost ethmoidal cells bulge into it and mold it into such a contour. The anterior part of the fovea lies more superior than the posterior part, since the anterior cranial fossa descends 15° from a horizontal plane as it passes posteriorly.

The lateral wall of the box is the lamina papyracea or os planum. It is a flat, smooth, rectangular plate of bone articulating with the frontal bone superiorly, the lacrimal bone anteriorly, the maxilla inferiorly, and the lesser wing of the sphenoid bone posteriorly. Along the frontoethmoidal articulation lie two foramina, the anterior and posterior ethmoidal foramina. Through these pass branches of the ophthalmic artery (internal carotid) and nerve (trigeminal) to supply blood and sensation to the mucosa of the ethmoidal air cells.

The anterior side of the ethmoidal box abuts the lacrimal bone, the smallest of the facial bones. This bone is insinuated between the ethmoidal block posteriorly and the frontal process of the maxilla anteriorly. The importance of the lacrimal bone is that it is frequently pneumatized with the group of anterior ethmoidal cells termed the agger nasi. Cells in this group are the first ones entered during an external ethmoidectomy. On its lateral side, the lacrimal bone forms the posterior half of the lacrimal fossa.

The posterior part of the ethmoidal box is formed by the back walls of the posterior ethmoidal cells. Because a large ethmoidal cell often abuts the sphenoidal sinus, these cells frequently share a common osseous wall.

The inferior and medial walls of the ethmoidal box must be considered together, for they comprise almost a single slightly convex curved plane bowing into the nasal chamber. Thus, the ethmoidal sinuses do not lie directly atop the maxilla but touch the latter only at the upper medial part of the maxillary sinus (see Chapter 8). Projecting into the nasal chamber from the medial wall of the ethmoidal block are the turbinates. The support of these structures is a partition of bone - the baswal lamella - that continues from the base of the turbinate and traverses laterally through the mass of ethmoidal cells to attach to the medial side of the lamina papyracea. The inferior, middle, and superior turbinate lamellae internally divide the intramural ethmoidal cells into anterior, posterior, and postreme groups. The lamella in each case is not a straight divided because the developing air cells push and distort what was its original linear position in the fetal ethmoid bone. The anterior and posterior ethmoidal arteries enter the block of ethmoidal sinuses just at the sites where the basal lamellae of their middle and superior turbinates join the lamina papyracea.

In general, the cells of the anterior ethmoidal group are more numerous (two to eight) but smaller, whereas those of the posterior group are larger but fewer in number (one to seven). Because of their number, the cells in the anterior group are commonly further subdivided, according to their location or ostium site:

- Anterior ethmoidal cells
  - Frontal recess cells
  - Cells of ethmoidal infundibulum
  - Bullar cells
  - Conchal cells
  - Extramural ethmoidal cells
- Posterior ethmoidal cells
  - Intramural cells
  - Extramural cells.

The number of anterior ethmoidal cells depends on their size; for the larger they become, the fewer they are in number. All drain into the middle meatus under the middle turbinate.

The most anterior of the ethmoidal cells are those in the frontal recess group, where the range may extend from total agenesis to as many as four cells. These cells grow upward into the frontal bone and indeed are sometimes the origin of the frontal sinuses. Some of them also may grow under the floor of the frontal sinus and bulge upward into it, creating a frontal bulla cell; or they may appear across the orbit as an orbital ethmoidal sinus. Should they expand downward, they may encroach on the nasal frontal duct and cause it to have a serpentine course. When the frontal sinus develops from one of these cells, then a nasofrontal duct exists. On occasion, however, the frontal sinus is a direct extension of the whole frontal recess. In such a case the sinus drains into the nose, and only a frontal ostium exists.

The infundibular cells are small, vary up to four in number, and drain directly into the infundibulum. They usually pneumatize the lacrimal bone and are termed the agger nasi; on occasion one may enter the frontal bone to become the frontal sinus.

The bullar cells, one to six in number, cause the bulla to appear rounded in the middle meatus. They commonly are evaginations from a furrow lying on the bulla's medial and superior surface, termed the suprabullar furrow or sinus lateralis. It is usually these cells that expand in various directions and, often, account for the wide extramural ethmoidal extensions.

The posterior ethmoidal cells are quite large because they are few in number and because the ethmoidal capsule is much wider posteriorly than anteriorly. These cells, too, often expand beyond the confines of the ethmoid bone into the sphenoid, palatine, maxilla, and middle turbinate.

Clinical Correlations

Knowing the embryology of the ethmoidal air cells provides some help in understanding this part of paranasal sinus anatomy. The growth of air cells, each struggling for space in the ethmoid and adjacent bones, results in a haphazard arrangement that makes anatomic comprehension a difficult task. However, such knowledge is of paramount surgical importance, since these sinuses lie adjacent to many vital structures: orbit and optic nerve, brain, cavernous sinus, and internal carotid artery. Obviously, the proximity of such structures requires a precise knowledge of those few surgical landmarks possessed by the ethmoid bone.

The lamina papyracea is the most constant of the walls of the ethmoidal capsule and contains the most definite surgical landmarks. Study of a skull will reveal that the ethmoidal sinuses are separated from the orbit by only this paper-thin plate of bone. Indeed, so thin is the bone that occasionally natural dehiscences occur in its surface, which permit the development of an orbital cellulitis from an ethmoiditis. At the superior edge of the lamina papyracea, at its articulation with the frontal bone, lie the two ethmoidal foramina, each containing an arterial and a neural twig. A line connecting these is parallel and just inferior to the dura of the anterior cranial fossa. The posterior foramen lies 3 to 8 mm anterior to the optic nerve. Occasionally, a third foramen is found.

The other landmarks of the ethmoid bone are confined to its medial surface - the middle and superior turbinates and the bulla ethmoidalis lying under the middle turbinate. The middle turbinate is an osseous shelf approximately 3.5 to 4 cm in length and sometimes pneumatized with an ethmoidal cell (4 to 12%). Its anterior attachment is rooted to the cribriform plate. From this origin its free edge slants posteroinferiorly 15° so that its posterior tip lies at or immediately inferior to the sphenopalatine foramen. Just in front of its anterior tip lie the agger nasi cells, and superior to these are the cells of the frontal recess. Under this turbinate lie the cells of the bulla ethmoidalis and the ethmoidal infundibulum. Posterior and superior to its body lie the posterior ethmoidal cells. Its posterior tip marks the farthest extremity of intramural cell development. Medially, the cribriform plate with olfactory fibers attached to the mucosa of the turbinate are found.

The superior turbinate is a small projection of the ethmoid bone, approximately 1.5 cm in length. Its body lies lateral to the middle turbinate, and its anterior tip lies on a parallel with and 1 cm anterior to the ostium of the sphenoidal sinus. Its posterior tip points directly to and ends at the anterior edge of the sphenopalatine foramen. Thus, both middle and superior turbinates' posterior tips lie at the sphenopalatine foramen and usually within 3 to 5 mm of each other.

4. The Frontal Sinus

Embryology

The nasofrontal region arises from an evagination of that deep anterosuperior part of the middle meatus termed the frontal recess. In a fetus of 3 to 4 months, furrows are present that deepen into a single large pit or several small pits. These pits can be recognized at birth; as they continue to gradually expand, their growth pushes one or two of them upward into the frontal bone. By 6 years, the sinus has grown sufficiently large to be just visible in the frontal bone roentgenographically. The upward expansion continues, with the cell at first laying closer to the posterior table than to the anterior one before it finally rests in the cancellous bone midway between the two tables. Consequently, the frontal sinus originates either as a direct extension of the entire frontal recess or from one of its pits. On rare occasions, the sinus develops as an extramural expansion of one of the air cells of the ethmoidal infundibulum.

Anatomic Considerations

On occasion (4%) the sinus fails to develop, but more commonly its chambers develop asymmetrically in size. The adult sinus averages 28 mm in height, 27 mm in width, and 17 mm in depth. The length of the intersinus septum depends on the height of the two frontal sinuses, and its location is in the midline only in its lowest part - at the root of the nose. Although at all times each sinus cavity is a single chamber, it is compartmentalized by the numerous intrasinus septa.

Whether or not a nasofrontal duct will serve as the drainage portal of the sinus depends first on the embryology of the sinus for its existence. When the sinus develops directly as an extension of the whole frontal recess, then only a frontal ostium that drains directly into the anterior part of the middle meatus will exist. However, when the origin of the frontal sinus is from a frontal recess furrow or (more specifically) when the sinus originates from one of the cells of the ethmoidal infundibulum, then a nasofrontal duct certainly exists. In the latter instances, the expanding anterior ethmoidal cells of the frontal recess by their growth distort and displace the position of the duct. Thus, the nasofrontal duct always presents a serpentine course upward toward the frontal sinus. From such a description it is obvious that only by chance can there be an alignment of the nasofrontal duct with the hiatus semilunaris; therefore, more often the frontal sinus drains not into the hiatus but superior to it.

On frequent occasions a second frontal recess cell grows upward into the frontal bone. Since the first is the frontal sinus, the second presents in the floor of the frontal sinus as a bulge. Such a second cell is termed a frontal bulla cell. Bulla cells are rarely over 1 cm in diameter.

Clinical Correlations

Since the sinus grows upward into the frontal bone, it is deeper in its anteroposterior diameter near the midline at the level of the supraorbital ridge than it is elsewhere. Furthermore, such a pattern of growth causes the floor of the frontal sinus to be thin. Because of this thin bone it is best to approach the sinus through its floor for trephination. Also, the thin floor permits the controlled fracture necessary for an inflammatory or a neoplastic lesion. Similarly, the intersinus septum is usually thin and is absent only in disease states.

Because the nasofrontal duct is tortuous and inconstant in its position and because frontal sinus disease is relatively infrequent, using blind cannulation of the duct to establish sinus drainage is not recommended. For drainage, external trephination may be used. Alternatively, from the intranasal route it is approached through the agger nasi cells. These are the most constant ethmoidal cells in occurrence, are quite large in size, and lie at an accessible location in the anterior part of the middle meatus. Direct visualization or endoscopy may be used.

The proximity of this sinus to the marrow part of the frontal bone permits spread of infection from the sinus directly into the bloodstream. This can account for abscesses that develop elsewhere in the skull or in more distant sites when an infection occurs within the sinus.

Anomalies

Frontal sinuses do not commonly present a uniform size to each other or to a comparative study in examining multiple anatomic specimens. The sinus may expand posteriorly and medially atop the orbit or laterally toward the external canthus, but most sinuses grow superiorly near the midline to a height of 3 to 4 cm.

Sometimes very large sinuses will develop in gigantism resulting from excess pituitary growth hormone. The lumina may grow so large as to approach the vertex of the skull. In contrast, in 4% of specimens, there is no development of the sinus at all.

5. The Sphenoidal Sinus

Embryology

The sphenoidal sinus begins in the 4-month of fetal life as an evagination from the posterior part of the nasal capsule into the sphenoid bone. With continued expansion the size of the cavity increases to that at birth it measures 2x2x1.5 mm, being smallest in the anteroposterior dimension. Continued expansion often causes the sinus to attain a large size before growth ceases in early adulthood. The average adult cavity measures 14x14x12 mm, again the anteroposterior expansion being the shortest.

Anatomic Considerations

From the preceding measurements of the size of the adult cavity, it might be inferred that the sinus is often round. So it is in the majority of cases. However, the sinus sometimes expands by diverticula off the main lumen into the various parts of the sphenoid bone. Hence, the greater wing often contains a pneumatic extension, and sometimes also the lesser wing as well. On rare occasions even the pterygoid plates may become pneumatized. However, in most cases it is the body of the sphenoid that alone becomes aerated.

Clinical Correlations

Depending on the degree of pneumatic expansion that exposes the pituitary fossa to the sinus lumen, the sinus is classified as nonpneumatic, presellar, or sellar. A presellar sinus is a small pneumatic one, whereas a sellar one exposes the pituitary fossa on its anterior and inferior surfaces. Large sellar sinuses will sometimes expand so widely that the internal carotid artery and nerves adjacent to the sinus lumen may be thrown into bold relief as ridges. Thus, the carotid artery, optic, ophthalmic, and mandibular divisions of the trigeminal or the vidian nerve may lie separated from the sinus mucosa by only a thin layer of bone. Indeed, it is not unusual for these structures to be found immediately under the mucosa, without a bony covering. For this reason any dissection should be carefully performed on the lateral wall of the sinus.

The other walls of the sinus are of variable thickness depending on the degree of pneumatic expansion. Even when the sinus is small, its superior wall is usually the thinnest - being often just 1 mm thick. Such proximity to the dura and optic chiasm just above the sinus makes these structures vulnerable if the wall is penetrated with a surgical instrument.

The posterior and inferior walls do not often present a problem. The posterior wall may be thin but is easily examined visually, since it usually lies directly in the midline path of the surgical dissection. In addition, the pituitary fossa also acts as a landmark in a large pneumatic sinus. The inferior wall is always quite thick and so not easily penetrated.

The ostium of the sphenoidal sinus is usually round and located at least one-half the way up the face of the sphenoidal sinus. Although it may vary between 1 and 3 mm in size, it is more often near 3 mm in diameter. It usually lies 2 to 5 mm from the dura and the same distance from the midline. It is often hidden from view by the middle or superior turbinates during anterior rhinoscopy.

The intersinus septum is always thin and often displaced from the midline except at the position where the sinus anteriorly is aligned with the vomerine part of the nasal septum. This often causes the sphenoidal cavities to be asymmetrical, which should be recalled in performing a sphenoidotomy. Indeed, the intersinus septum may be developed such that it is attached on the posterolateral sinus wall on or adjacent to the carotid artery.

Anomalies

The generous pneumatic expansion that characterizes the size of these sinus cavities results in their being the largest of the paranasal sinuses. Such growth may extend the sinus lumen into the lesser and greater sphenoidal wings and the pterygoid portion as an intramural extension. Extramural extensions of the sphenoidal cavities are sometimes found even in the maxilla.

Anatomists and clinicians who have studied paranasal sinuses cannot easily ascribe anomalies to these cavities. Normally they are large, so their contact with nerves and arteries is common and cannot be construed as anomalous.

Part Two

Anatomic Study of Coronal Sections and Radiographs of the Paranasal Sinuses

Often anatomic atlases and textbooks depict anatomy only through an artist's conception in the form of an illustration. The surgeon, however, often requires the more exact anatomic relationships shown by a dissection.

The following coronal head sections of cadavers are offered as an aid in understanding surgical relationships of paranasal sinus anatomy. There are three specimens. The first specimen was derived from an infant 6 months of age; the second, from a child 9 years old; and the last specimen is from an adult. These ages were selected because the paranasal sinuses constantly expand in size until adulthood, altering the relationship of the sinuses to the adjacent orbital, oral, and endocranial contents.

The site of each coronal cut in relation to the head of the specimen can be ascertained from the drawing that precedes the anatomic series in which it is included. On the page with a specimen are notes on salient anatomic characteristics. The number of each note corresponds to the number of the accompanying anatomic plate.

Radiographs have been taken in the standard recommended views for depicting the paranasal sinuses and are provided in a further effort to correlate the anatomy with clinical medicine.

Part Three

Surgical Procedures on the Paranasal Sinuses - Conventional

10. The Maxillary Sinus

Maxillary Sinus Irrigation

Indications

Antral irrigation is most often indicated to cleanse the maxillary sinus of sequestrated, purulent secretions in order to hasten resolution of a sinusitis treated medically. These secretins may be the result of either a subacute or a chronic infection. Irrigation may also be performed to obtain the secretions from a maxillary sinus for cell study when a malignant neoplasm is suspected.

Surgical Anatomy

The bone of the maxilla in the upper central part of the inferior meatus and in the canine fossa is very thin, so the sinus should be entered at these points. If the trocar is turned on its long axis, as in drilling with a bit, it will easily pass through this thin bone into the sinus lumen without alarming the patient.

The infraorbital nerve is located 1 to 2 mm below the infraorbital rim at the mid-pupillary line and can usually be palpated.

The nasolacrimal duct lies within the first centimeter of the inferior turbinate's anterior attachment in the inferior meatus.

In children, the floor of the maxillary sinus may be above the nasal floor and may be confirmed using a Caldwell view sinus X-ray.

Surgical Techniue (Inferior meatus route)

1. Moisten a wisp of cotton on a cotton carrier with 5% cocaine. This pledget should be painted several times and left in place in the inferior meatus until the mucosa in the anterior half of the meatus is thoroughly anesthetized. Using a 30-gauge long needle, inject a local anesthetic into the inferior meatus to further the anesthesia. Blanching of the mucosa indicates adeqaute vasoconstriction.

2. A Lichtwicz irrigating trocar and its contained obturator or an 18-gauge spinal needle is placed into the central part of the meatus, 1.5 to 2 cm behind the anterior attachment of the inferior turbinate. In this direction the trocar usually lies alongside the anterior nasal septal spine in the anterior nares and points to the posterior part of the orbit. Twist the cannula between the thumb and index fingertip and exert gentle pressure. The needle should enter the lumen of the sinus easily after several millimeters.

3. When the sinus lumen has been entered, removed the obturator, attach a syringe to the trocal, and aspirate the sinus cavity. After obtaining air or secretions, irrigate the sinus with slightly warmed normal saline.

   If blood is aspirated, the needle is probably in a large submucosal vessel. Either push the needle slightly farther into the sinus or withdraw it until air or secretion is obtained. If the needle is totally withdrawn, an alternate site in the meatus can be selected.

4. Continue irrigation of the sinus with warmed saline until the secretions are clear.

5. When irrigation has been finished, remove the trocar. Do not fill the antrum with air to displace the irrigant, since fatal air embolism might occur. Ask the patient to blow his nose to cleanse it of secretions.

Surgical Technique (Canine fossa route)

1. With the patient lying supine, infiltrate with a local anesthetic the soft tissues of the cheek overlying the antrum to be irrigated. The anesthetic should be introduced via the oral route just above the canine tooth.

2. After several minutes have elapsed, insert the Lichtwicz irrigating trocar into the tissues and push it along the face of the maxilla to a point 1 cm under the infraorbital rim and 1 cm lateral to the nasofacial line.

3. Tip the trocar hub so that the needle points directly posteriorly parallel to the Frankfort horizontal line, and away from the eye. The upper lip will be tented by the trocar.

4. Place the thumb of the opposite hand on the infraorbital rim to prevent any damage to the orbit should the needle slip.

5. Using a twisting motion of the hub, slowly insert the trocar into the antrum.

6. Bring the patient to a sitting position, aspirate, then irrigate the antrum.

Complications (Inferior meatus route)

The orbit should always be considered during instrumentation of the sinus. The needle should enter the sinus after several millimeters. If the needle has entered deeply into the antral lumen and aspiration fails to produce air or fluid, the orbit may have been entered. The trocar should be withdrawn until air or secretions can be obtained by aspiration.

If the cannula is not inserted far enough posteriorly into the meatus, it may slide off the medial wall of the maxilla and penetrate the soft tissues of the cheek anterior to the face of the maxilla. In this location, aspiration will not provide a return of air or secretions. This should arouse suspicion that an abnormal placement of the trocar has occurred. Also a disadvantage of the anterior placement of the trocar is that the bone in the anterior part of the inferior meatus is thick, making penetration difficult.

Bleeding after irrigation may continue from the nasal mucosa at the point of entry into the sinus. It can be controlled by elevating the inferior turbinate with a Cottle speculum and electrocoagulating the bleeding vessel. A Bucy-Frazier insulated suction tube works very satisfactorily for this purpose.

Complications (Canine fossa route)

There are only two main complications from using this route for irrigation of the maxillary sinus. One is damage to the infraorbital or superior alveolar nerves with anesthesia and paresthesias occurring for several wekks during regeneration of the nerve. The second is cellulitis with eventual cheek abscess that develops because pus drains from the antral lumen through the tract made by the irrigating trocar. A cheek abscess requires intraoral incision and drainage for resolution.

Nasal Antrostomy (Nasal Antral Window)

Definitions and Indications

The surgical creation of an opening in the medial wall of the maxillary sinus is known as nasal antrostomy. The most frequent reason for performing this procedure is to create an adequate route of drainage for the egress of purulent sinus secretions. Some patients tend to have recurrent acute maxillary sinusitis, a frequent sequela of each upper respiratory infection or a recurrent accompaniment of seasonal nasal allergy. Generally, the basic cause of these recurrent sinus infections is a stenosis of the natural sinus ostium, either from prior sinus infections or from blockage by edematous allaergic mucous membrane or a nasal polyp. Regardless of its cause, interference with sinus drainage always promotes a continuation of the sinusitis. The nasal antral window prevents this accumulation so that resolution of future acute infections will proceed promptly. Additionally, chronic sinusitis will resolve if the natural drainage pathways can be reestablished.

The window may also be used for other reasons: to inspect or do a biopsy of a mass within the sinus lumen, to promote drainage of necrotic debris as it sloughs during irradiation of a malignant maxillary sinus neoplasm, to remove a foreign body such as a tooth rootlet fractures into the sinus during dental extraction, or to reduce a fracture of the malar bone. Creating the window is also a step in the Caldwell-Luc operative procedure.

A variance in medical thought exists as to the best location for the nasal antral window. Proetz has demonstrated that the inferior meatal location of this window with its subsequent mucosal scarring will interrupt the usual pathway of ciliary mucus as it flows toward the natural ostium. For this reason, some clinicians favor enlarging the natural ostium. Fear that enlarging the natural ostium results in scarring and possible further stenosis of the ostium is unwarranted. A natural ostium antrostomy is the only procedure that can be used in children if pneumatic expansion of the sinus is not large and the sinus floor has not expanded to permit inferior antrostomy.

Clinical experience has demonstrated that the window provides little relief for patients who complain of pressure and tension in the nose, eyes, and cheeks in the face of unrevealing diagnostic efforts.

Inferior Meatus Route

Surgical anatomy

The anterior end of the inferior turbinate is attached to the lateral wall of the nose. To gain access to the inferior meatus for performing the antrostopy, this attachment often is severed cleanly with a knife.

The bone of the maxilla in the inferior meatus, close to the attachment of the inferior turbinate, is quite thin. For this reason the antrostomy is begun most easily in this thin bone.

Anteriorly, in the first 1 cm of the inferior meatus lies the inferior end of the nasolacrimal duct.

Posteriorly in the bone of the inferior meatus course the branches of the descending palatine artery. The bone of the meatus should not be removed so far posteriorly as to injure these vessels.

The anterior, middle, and posterior superior dental nerves lie in the medial wall of the maxillary sinus. Some of these narrow filaments may be severed in performing the antrostomy, with resultant dental pulp denervation.

Surgical technique

1. Intranasally, infiltrate an injectable local anesthetic containing a vasoconstrictor into the anterior attachment of the inferior turbinate.

2. Topically apply cocaine to the mucosa of the meatus and the lateral aspect of the mucosa of the inferior turbinate.

3. Sever the anterior attachment of the inferior turbinate with a cold knife.

4. Fracture the inferior turbinate superiorly. The anterior portion is best fractured by opening the tips of the thin-bladed Cottle nasal speculum after its insertion into the meatus. The posterior portion of the turbinate is elevated with the blunt end of a no 7 scalpel handle.

5. With the meatus now fully exposed, further anesthetize and vasoconstrict the entire anterior three-fourths of the mucosa of the meatus. Thereafter, withdraw the pledget.

6. Into the meatus place a fresh 1 cm in diameter rolled neuropledget with attached string. If this is placed two-thirds of the way posteriorly into the meatus, it will hold the turbinate upward. Also the white pledget acts as a

reflector of light to increase visibility in the meatus; if the cottonoid becomes saturated with blood, the attached suture makes identification of the cottonoid easier.

7. The incision to create the meatal flap begins posteriorly on the nasal floor half the distance back in the meatus. The incision is brought upward and forward for 2 cm. After elevation from the meatal bone, the flap is reflected onto the nasal floor.

8. Enter the sinus with a perforating punch in the thin bone of the meatus. If a posterior site is chosen, only an upward-biting Kerrison rongeur is needed to create the antrostomy by working forward from behind.

9. Remove all bone chips and foreign bodies from the nasal chamber. Electrocauterize all bleeders using point cautery. Fold the mucosal flap across the inferior lip of the bony window into the maxilloary sinus. Packing is not usually necessary.

10. An alternative technique uses the rattail rasp. The tip is used to gently perforate the thin medial sinus wall 2.5 cm behind the anterior attachment of the inferior turbinate. A gentle rocking motion is used to enlarge the antrostomy to a 2 cm x 1 cm size. Pressure is toward the nasal floor. Packing may be necessary if precise cautery is not possible.

Complications

Bleeding is probably the only early complication of nasal antrostomy. It usually originates in the nasal mucous membrane and responds either to electric catuery with a Bucy-Frazier Teflon-coated insulated suction tube or to light tamponade with a pack.

Mucosal adhesions between the free edge of the turbinate and the nasal floor or the nasal septum are sometimes a late postoperative complication. These can be easily lysed as an offic procedure by cutting with a myringotomy knife.

Bony closure of the window by growth of new bone might be construed as a late complication. However, although some closure occurs in most patients, it is less likely to develop if the bone of the meatus is removed to at least the level of the nasal floor and the preserved mucosal flap is folded into the sinus.

Middle Meatus Route

Surgical anatomy

The middle meatus contains thin bone surrounding the natural ostium, but the area is surrounded by the elevations of the uncinate ridge, ethmoidal bulla, and inferior turbinate and is covered by the middle turbinate.

Surgical technique (For endoscopic technique see Chapter 17).

1. Apply a topical anesthetic to the lateral part of the middle turbinate and the mucosa of the middle meatus.

2. Elevate the middle turbinate medially and superiorly with the blunt end of a no 7 scalpel handle. Hold the turbinate superiorly with a cottonoid to which is attached a silk suture.

3. By inspection locate, in the anterior part of the middle meatus, a ridge that runs diagonally in a superior to inferior and posterior direction. This is the uncinate ridge, and just posterior to it lies the infundibulum of the middle meatus containing the natural ostium.

4. With a curved, natural ostium cannula, locate the natural ostium; then, with a perforating punch adjacent to the cannula, enlarge the ostium. If possible, use a small Kerrison rongeur or Ferris-Smith biting forceps to further this enlargement.

5. The final window size will not be large, because of the lack of exposure and the angle of working in the nose.

6. Remove all cottonoids and bone chips. Packing with a gelatin sponge for hemostasis can be done but is usually not needed.

Caldwell-Luc Procedure

Definition and Indications

In the years 1893 and 1897 the technique of a surgical oprtation to rid the maxillary sinus of a purulent infection was independently described by an American and a French surgeon, each unknown to the other. At present the title of this operative procedure bears both of their names. In their original descriptions, these surgeons advocated removing all tissue lining the maxillary sinus and then establishing counterdrainage into the nasal chamber through the inferior meatus.

Although at present the procedure is performed in a manner similar to that described by each surgeon, a more conservative thought prevails, in that only pathologic tissue is removed from the sinus. Furthermore, whereas the original operation was conceived to remove tissue of inflammatory origin, indications for the procedure have now been extended so that it is used for the removal of a sinus foreign body, the biopsy of a sinus neoplasm, or the reduction of an orbital floor or malar bone fracture. Also, the technique is used as an approach for surgery in the pterygopalatine fossa.

Surgical Anatomy

The oral mucosa covering the alveolus is tightly adherent to the underlying periosteum. As the mucosa rises to the apex of the buccogingival sulcus, it becomes less attached and more lax because of an abundant amount of soft tissue in the submucosa. The oral horizontal incision used in the procedure should be made in the lax portion of the mucosa near the apex.

This creates an inferior cuff of mucosa on the lower flap, and later the surgical wound can be securely approximated by sutures to avoid an oral antral fistula. Some surgeons prefer to make the incision in the gingiva immediately adjacent to the teeth.

When the Caldwell-Luc procedure is to be performed in conjunction with the closure of an oral antral fistula, the incision should be planned with an oral flap to cover the fistula. If need be, the buccal incision can be made vertically.

The bone of the canine fossa is the thinnest in the face of the maxilla and is the site chosen to enter the maxillary sinus.

The roof of the sinus is composed of very thin bone and can be easily penetrated with forceful curettement. The other walls can be curetted without such worry.

Tooth rootlets may project into the floor of the sinus and cause sharp ridges, in between which inflammatory diseased tissue can reside. For these reasons the floor of the sinus should be thoroughly inspected at the time of surgery.

The nerves supplying sensation to the maxillary teeth course in the medial wall of the antrum. If possible, care should be exercised to prevent damage to these filaments during curetting of the medial wall of the sinus cavity.

Surgical Technique

1. Under general or local anesthesia, the line of incision and the soft tissue overlying the maxilla are infiltrated with the anesthetic containing a vasoconstrictor to reduce hemorrhage. Make the incision straight down to bone. When local anesthesia is used, a regional block of the maxillary sinus can be obtained by injecting the maxillary nerve in the pterygopalatine fossa via the greater palatine canal.

2. Elevate the anterior cheek flap from the face of the maxilla until the maxillary nerve is noted and preserved as it emerges from the infraorbital foramen at the midpupillary line.

3. Enter the sinus in the canine fossa. Because of the state of development it is wise to enter a child's sinus more superiorly on the face of the maxilla, superior to the tooth buds, depending on the size of the sinus cavity as determined by roentgenographic study. Should a tooth bud become loosened from its developing site, replace the tooth in its fossa. Generally, however, a middle meatus route is chosen in children. Alternately, endoscopic techniques may be used (Chapter 17).

4. Restrict curettement in the antrum so that it involves only inflammatory diseased tissue.

5. Locate the site for an inferior nasal antrostomy by transnasally placing a trocar through the inferior meatus into the sinus lumen. Then remove the bone of the

meatus around the trocar by gouge and mallet to create the window. Incise the mucosa sharply from the sinus side and then fold it into the nose. For a superior antrostomy, the natural ostium is found in the posterosuperior portion of the medial sinus wall. A Kerrison rongeur can be used to enlarge it. Anteriorly the nasolacrimal duct must be considered.

6. After surgery, packing of the sinus lumen is often necessary to control bleeding. Use a pack of 1-inch gauze, impregnated with petrolatum or antibiotic ointment and brought out the nasal antrostomy, and close the original buccal incision by absorbable sutures. Any serrated edges in the anterior antrostomy should be smoothed to prevent catching of the gauze packing.

7. In the Denker procedure, the piriform crest medial to the canine fossa and the first centimeter of anterior medial wall of the maxillary sinus are removed with chisel and rongeur technique. This permits more exposure of the antral lumen, sometimes needed to remove large benign lesions.

Complications

Bleeding may occur but is uncommon if the sinus cavity is packed. The most common site for bleeding is the nasal mucosa at the site of the nasal antral window.

Pack removal is easily done, but during withdrawal a pack sometimes becomes caught on the bony edge of the antrostomy. Twisting the pack often frees it, so that forceful pulling is not needed. Furthermore, constant twisting of the pack gives less chance of disturbing the mucosal flap in the nasal antral window.

On closure of the mucosal incision, sewing from the freely mobile tissue toward the anchored gingiva prevents tearing and dehiscences.

Transantral Ethmoidectomy

Indications

Sometimes it is necessary while doing a Caldwell-Luc procedure to perform an ethmoidectomy for disease involving both the antrum and the ethmoidal cells. In such instances, an approach to the ethmoidal cells can be gained through the antrum. Often more than one approach is used simultaneously for improved visualization and two-point orientation. This is also a primary procedure for orbital decompression to provide relief of exophthalmos.

Surgical Anatomy

All ethmoidal cells except the most posterior ones lie medial to the medial wall of the maxillary sinus. The medial wall of the antrum often lies directly under the lamina papyracea, so that if a vertical line is drawn through the lamina papyracea, it passes either medial to the maxillary sinus or along the course of the medial wall of the maxillary sinus itself. Contact between the antrum and the ethmoidal cell block anteriorly is barely a few millimetyers, whereas posteriorly contact is much greater. The reason that the cells are larger posteriorly is that the lamina papyracea slants laterally slightly in its posterior extension. This is not so striking in a child's development.

This bone separating the ethmoidal cells from the antrum is sometimes quite thick and may need a firm rongeur for removal. This same anatomic feature, fortunately, protects the globe from injury.

Posteriorly, the ethmoidal air cells do not extend further than the posterior antral wall.

The optic nerve is enveloped by the posteromost ethmoidal cells; not uncommonly dehiscences occur.

Surgical Technique

1. Perform a Caldwell-Lucx operation, as described above.

2. Locate the ostium of the maxillary sinus from within the lumen of the antrum.

3. The bone immediately superior to the ostium is the ethmoidal bulla.

4. Enlarge the ostium by removing ethmoidal cells superiorly, anteriorly, and posteriorly.

5. The lamina papyracea is used as a landmark throughout the procedure. Medially, all air cells are removed.

6. Intermittent packing with topical epinephrine-soaked gauze will stop the bleeding. Alternating sides prevents any delay.

Complications

Blindness can be the result of any operation on the antrum or any of the paranasal sinuses, when the eye is in the field of the operative procedure.

Decompression of the Orbit for Malignant Exophthalmos

History

There are five approaches to decompression of the orbit by bone removal. Sewall described removal of the lamina papyracea after complete ethmoidectomy. Removal of the frontal sinus floor is ancillary to this procedure. Hirsch decompressed the eye by removing the orbital floor. The Walsh-Ogura approach combines the above two procedures. This gives considerable space for decompression. Krönlein removed the lateral orbital wall through an orbital rim incision. Its drawback is minimal decompression. Naffziger's procedure is an intracranial undertaking. Possible pulsatile ophthalmopathy may occur after this later procedure.

Those decompressions pertaining to removal of sinus-related bone are very efficacious with little morbidity. Their only drawback is that the optic nerve itself is not easily decompressed; generally, a neurosurgical approach from above the eye is used.

Transantral Ethmoidectomy for Exophthalmos

Surgical Technique

1. The same approach as for transantral ethmoidectomy is used. The ethmoidectomy is performed.

2. Remove the bone of the orbital floor. Outline and preserve the infraorbital nerve.

3. Use the periosteum as a guide while removing the lamina papyracea.

4. After the osseous work is completed, the periorbitum may expand to fill the bony defect. To gain more decompression this periorbitum may be cut linearly. These cuts extend from posterior to anterior. Any bleeders are mildly bipolar cauterized. This permits the orbital fat itself to herniate into the antrum and the space created by the exenteration of the ethmoidal cells.

Hemorrhage may be a complication, and if the bleeding occurs during surgery, tamponade is used to control it, but the packing should be inserted cautiously into the antral cavity, so that the eye is not damaged by the pressure.

Maxillary Artery Ligation - Caldwell-Luc Approach

Indications

In epistaxis, when the site of the bleeding vessel lies below the level of the middle turbinate, the hemorrhage is often considered to be from the maxillary artery or one of its branches. When packing is ineffective in controlling the epistaxis, ligation of the artery either in the neck (external carotid) or in the pterygopalatine fossa is often successful in controlling the bleeding. Preferably, three arteries are ligated: the maxillary, sphenopalatine, and descending palatine. Thus, direct, retrograde, and anastomotic flow are minimized. The artery can also be ligated in this fossa if it supplies an angiofibroma of the nasopharynx.

Surgical Anatomy

The pterygopalatine fossa lies in the cleft between the maxillary sinus and the pterygoid plates of the sphenoid bone. Seven foramina open into it: laterally, the pterygomaxillary fissure; superoanteriorly, the infraorbital foramen; superposteriorly, the foramen rotundum; posteromedially, the pterygoid canal; medially, the sphenopalatine foramen; and inferiorly, the pharyngeal and posterior palatine canals. Its contents are the maxillary artery, the maxillary and vidian nerves, the sphenopalatine ganglion, and the internal pterygoid muscle.

The maxillary artery is the last branch of the external carotid artery and enters the pterygopalatine fossa through the pterygomaxillary fissure. As it courses this interval it hugs the periosteum, covering the posterior wall of the maxillary sinus.

The branching pattern of the vessel varies considerably in the fossa. There are five branches before the artery enters the nasal chamber as the sphenopalatine artery. These are the posterosuperior alveolar artery, vidian artery, pharyngeal artery, infraorbital artery, and descending palatine artery.

The maxillary nerve and sphenopalatine ganglion lie medially and superior to the artery; if possible, injury to these structures should be avoided.

Surgical Technique

1. Study paranasal sinus radiographs to determine the size and configuration of the antrum. A small, undeveloped antrum or one severely sclerosed from infection or prior surgery probably contraindicates this procedure. In such instances, ligation of the external carotid artery in the neck may control the bleeding.

2. Perform the Caldwell-Luc procedure as previously described. Use a self-retaining McCabe or postaural retractor to hold the upper cheek flap retracted in this procedure.

3. Scrape the mucosa from the posterior wall of the antrum with a curette, if it is thickened. When the mucosa is thin, elevate it as a flap based laterally inferiorly and retracted against the lateral wall or floor of the maxillary sinus.

4. Using a gouge and mallet and rongeuring with a Hajek-Koffler punch forceps or a Kerrison rongeur, remove most of the posterior bony antral wall, especially the superior and medial corner of the antrum. Removal of the orbital process of the palatine bone best exposes the field.

5. Incise sharply in an inverted U manner the thin periosteum that covers the posterior bony antral wall, being careful not to penetrate deeply. Pull this periosteal flap into the sinus and lay it on the floor of the antrum.

6. Insert an aural attic hook or a nerve hook into the internal pterygoid muscle fibers and fat of the fossa to search for and gently pull the artery when located into the antrum. This and subsequent parts of the procedure are best performed under the surgical microscope, using a 300- or 400-mm objective lens.

7. Freeing the artery from surrounding tissue for the length of 1 cm will reveal that it has pulsations. This is an important characteristic to help locate and identify the artery.

8. Locate several branches as the artery courses medially. Because of abundant anastomoses it is wise to clip all branches. A hemostatic clip-applying forceps is very satisfactory.

9. Fold the periosteal flap back onto its original place and hold it in position with a small piece of absorbable geltain sponge. Small bleeders should be spot-electrocoagulated.

10. Close the original buccogingival incision with absorbable sutures.

Complications

The periosteum outside the posterior wall of the antrum is thin. Do not incise it deeply, or the maxillary artery lying behind it may be transected. If the artery should be accidently cut and bleeding cannot be controlled locally, then the external carotid artery in the neck should be ligated.

Each of the artery's many branches in the sphenopalatine fossa must be clipped; otherwise, because of the abundant anastomoses, the epistaxis will not be controlled.

The sphenopalatine ganglion and the maxillary nerve should not be injured, since ipsilateral anesthesia of the cheek and palate, decreased lacrimation of the eye, and dryness of the nasal mucosa will result from such injury.

Vidian Neurectomy

Indications

Vidian nerve section is performed in patients who have uncontrolled vasomotor nasal symptoms. The symptoms are similar to those of nasal allergy, but in these patients allergic investigations are negative. Symptoms are uncontrolled nasal congestion and watery discharge and itching of both nose and eyes. Rigorous medical therapy of systemic decongestants and possible psychiatric consultation should be tried before resorting to vidian neurectomy. The rationale of the procedure is based on a theory that the vidian nerve is overbalanced with parasympathetic fibers and on clinical studies that allude to the success of the procedure in patient care. The operation is less than totally successful but offers some patients relief.

Surgical Anatomy

The vidian nerve contains both postganglionic sympathetic and preganglionic parasympathetic fibers. The sympathetic fibers originate from the superior cervical ganglion, accompany the internal carotid artery in its adventitia, and leave the artery in the temporal bone as the deep petrosal nerve. The parasympathetic fibers originate in the nucleus of the tractus solitarius, travel with the facial nerve as the nervus intermedius, and after leaving the geniculate ganglion become the greater superficial petrosal nerve. Both petrosal nerves unite to form the vidian nerve, which passes through the pterygoid canal of the sphenoid bone to the pterygopalatine fossa. This canal and its nerve lie in the most medial part of the fossa and are in a direct line with the medial wall of the maxillary sinus. The foramen lies inferomedial to and is separated by a ridge from the foramen rotundum.

Surgical Technique

1. Peform the Caldwell-Luc operative procedure and enter the pterygopalatine fossa as for the ligation of the maxillary artery for epistaxis. Removal of orbital process of palatine bone markedly facilitates exposure.

2. Identify the maxillary artery; then double-clip and divide it for exposure. The division should be medial to the infraorbital artery. Any large veins should be similarly treated.

3. In the fossa search for a ridge of bone on the posterior medial wall of the fossa. The ridge separates the pterygoid from the rotundum foramen. The vidian nerve lies in a direct line with the medial wall of the antrum. It is medial and slightly inferior to the infraorbital nerve. The pterygoid canal is 1 to 2 mm in diameter.

4. Before sectioning nerve, use bipolar cautery to coagulate associated vessels. After the nerve is sectioned, use bone wax to control any further bleeding from the foramen. Terminate the procedure by replacing the mucoperiosteum of the posterior wall of the antrum over the fossa and holding it in place with absorbable gelatin sponge. With absorbable sutures, close the oral incision used for the approach to the antrum.

Complications

Bleeding may occur from the veins or small arteries in the pterygopalatine fossa and can be controlled by electrocoagulation or by clipping.

The bleeding that sometimes occurs from the pterygoid canal during surgery can be controlled with bone wax.

The ipsilateral eye usually becomes dry until the basal secretion of the glands in the conjunctiva adjusts to the neurectomy. During convalescence 0.25% methylcellulose eye drops are used during the daytime. At night, taping the eye may be necessary.

Oral Antral Fistula of Dental Origin

Indications

In order of frequency, after removal of the first, second, and third molars, as well as the premolars, a fistula may occur. In these teeth the roots commonly project into the floor of the maxillary sinus. Extraction of any one of these teeth may result in a tear of the mucoperiosteum of the antrum that covers the apices of the tooth rootlets. This permits contamination of the sinus by the oral cavity bacteria. A chronic maxillary sinusitis then often develops along with a permanent fistula.

Surgical Anatomy

If a dental fistula develops after extraction, the oral mucosa sometimes heals to such a degree that an almost imperceptible fistulous opening will exist in the alveolar mucosa. However, regardless of the size of the oral mucosal opening, the fistula in the alveolar bone is commonly several millimeters in diameter.

The surrounding tissues are very vascular and heal well, providing a tensionless suture line is achieved. Regardless of location, the principle for closure of a fistula is to remove any reactive granulation tissue followed by coverage with a healthy local flap.

Surgical Technique

1. Remove by curettement the diseased mucosa, granulation tissue, and bone surrounding the oral fistula, as well as the scar that lines the tract leading upward into the antrum.

2. Clarify mucosal edges by sharp dissection. This permits exact mucosal closure later.

3. Outline the particular flap to be used.

4. If an antrotomy is performed, preserve the bone that is removed from the face of the maxilla in entering the lumen of the antrum and break this into 2- to 3-mm pieces to be inserted into the bony dental fistula.

5. Inspect the antrum for polyps and fractured tooth rootlets and remove mucosa that is irreversibly diseased.

6. Create a nasal antral window if the natural ostium is small.

7. Pack the antrum to control bleeding if necessary.

8. Elevate the flap. Leave periosteum attached to the tip of the flap for easier suture placement on closure. The entire flap becomes very mobile as soon as the periosteal attachment of the flap is incised from the alveolar bone. This occurs at the base of the flap.

9. Without tension, approximate the buccal flap to the mucosa of the palate. Absorbable sutures such as chromic catgut may be used. If tension exists on the suture line because of immobility of the palatal mucosa, make a relaxing incision in the central part of the mucosa of the palate and elevate a palatal flap to reduce tension.

10. Close the Caldwell-Luc incision with absorbable sutures.

Complications

Complications are very uncommon from this surgical operation. Wound breakdown with reestablishment of the fistula may occur and is the most adverse reaction.

Maxillectomy

Indications

This procedure is performed to remove malignant lesions from the maxillary or maxilloethmoidal sinuses. Occasionally, some benign lesions such as the squamous "inverted" papilloma, mucormycosis, chronic osteomyelitis, or osteoradionecrosis may also require partial or complete maxillectomy.

Spread into surrounding tissues is not uncommon. The orbit lies superiorly. Growth through the palate or soft tissues of the face may occur. Since the posterior wall of the antrum lies just anterior to the pterygoid muscles, trismus signifies invasion of this region. Endocranial involvement occurs with growth of the neoplasm through the cribriform plate.

Paranasal CT/MRI scans are an indispensable aid in determining the extent of the growth of the neoplasm.

The procedure may be contraindicated when an extensive unresectable neoplasm exists. The individual surgical team must decide if significant chance of cure or useful palliation exists. In these massive tumors, close consultation with the patient and family are necessary to arrive at a conclusion.

Two adjunctive techniques may be useful in reducing blood loss during surgery. The first is embolization of the maxillary artery with Gelfoam to occlude its lumen. This should be done within 3 days preceding surgery to be most effective. Second is the use of hypotensive anesthesia techniques.

Surgical Anatomy

Lymph channels and nodes are present in the fatty portion of the cheek. The flap should be elevated within this layer. Only fat containing the subdermal plexus of vessels is left on the underside of the skin of the cheek, so that most of the lymphatic structures remain on the block.

Stensen's duct of the parotid gland lies adjacent to the upper second molar tooth. Care should be taken to prevent cutting this duct or its orifice in making the posterior limb of the oral incision of the flap.

When the orbit is not being taken with the block, it is important to recall that the facial nerve innervates the orbicularis oculi. Care is required to prevent damage to the seventh cranial nerve and consequent inability to close the eye postoperatively.

The internal maxillary artery should be sought and ligated in the infratemporal fossa as it crosses the internal pterygoid muscle. When it cannot be located, as the block is being removed later, the artery is often noted to be the last shred of soft tissue adherent to the block posteriorly.

The nasal bone is very thick at its articulation with the ascending process of the maxilla; thus, it has to be severed with a chisel.

The ethmoidal labyrinth is the thinnest osseous part of the block. It is best cut with a broad osteotome, which facilitates cutting a straight line. The anterior and posterior ethmoidal vessels are landmarks to the fovea ethmoidalis. Thus, the osteotome is placed on a line parallel and slightly inferior to these structures to prevent entry into the anterior cranial fossa. The ethmoidal block is pyramidal in shape, being wider posteriorly than anteriorly. Thus, a broader cut is performed posteriorly.

Surgical Technique

1. If the patient has a denture it should be brought to the operating room and placed in an antiseptic solution for later use during the procedure. If the patient has no denture, an acrylic plate or mold of the palate should be made so that it can be inserted after the maxillectomy to serve as support for the packing of the cavity. Alternatively, a large piece of foam rubber trimmed to size will mold and expand into the cavity postoperatively, effectively producing an obturator. The foam rubber fits snuggly and no sutures are needed.

2. Consider performing a tracheostomy for the administration of anesthesia and insurance of a postoperative airway. Otherwise, oral intubation is generally used.

3. Close the eyelids of both eyes with a horizontal mattress suture of 6-0 silk to protect the corneas. The sutures are placed through the lid gray lines to exactly coapt the lids. All eyelashes must be everted.

4. Inject the planned lines of incision with an anesthetic vasoconstrictor solution several minutes prior to making the incision to minimize bleeding.

5. The nasofacial incision is first made. Tumor spread into the orbital contents can then be ascertained. The orbital floor and periosteum are examined. If the periosteum is penetrated and the contents involved, then the orbit should be taken. The infraciliary cut is completed as well as the nasal and labial portions of the Weber-Ferguson incision. A Z-incision at the lip vermilion line prevents postoperative scar contracture and notching.

6. If the orbital contents are to be removed, the conjunctiva is spared to help with prosthetic globe reconstruction. An incision is placed around the limbus. Undermining of the conjuctiva proceeds to the sulci. Thereafter, the free margins of the limbus are closed in horizontal fashion with 4-0 chromic suture. The tarsal plates and lids are spared. Thus, a pocket is created which can accommodate a disc eye prosthesis. Alternately, the skin incisions can include both supra and infraciliary cuts. Thus, a circumferential incision is created

around the eyelashes. The tarsal plates, lids, conjunctivae, and remaining orbital contents are removed. This creates a flexible eyelid flap which is draped onto the superior orbital rim and roof on closure.

If the eye is being saved, an incision is placed in the infraciliary line. In placing the incision close to the lashes, postoperative edema is minimized. The angle between the infraciliary and nasofacial cuts should be 90°.

7. Next, elevate the cheek flap in the fatty layer. If neoplastic invasion of the flap has occurred, the cheek with skin should be resected with the block. A flap will need to be substituted for the cheek flap.

8. If the orbital contents are to be removed, periosteal incisions are placed at the orbital rim medially, superiorly, and laterally. The periosteal elevator easily separates the orbital periosteum from bone with the orbital contents diplaced in an inferior direction. Clips are applied to the anterior and posterior ethmoidal arteries. At the apex the contents are grasped with a clampo and divided. The ophthalmic bleeder is clamped and cauterized monopolarly. Suture ligation may be performed using a tonsillar snare suture technique. For continuity the orbit should be left affixed to the roof of the antrum.

   If the eye is not being removed, then elevate the periorbita from the bony orbital floor and from the lamina papyracea.

9. The cheek flap is retracted laterally and the masseter muscle attachment at the zygoma is divided. Next, make the palatal soft tissue incision with an electrical cutting knife to reduce bleeding. This incision does not divide the soft palate. Instead, it is continuous with the original lateral buccogingival incision, which is made to course posterior to the maxillary tuberosity of the alveolus and then medially to the midline just behind the posterior edge of the hard palate.

10. The maxillectomy entails five bone cuts. First, sever the zygomatic arch and the zygomatic process of the frontal bone with a Gighli saw. The malar eminence may be spared if not pneumatized by the antrum. Any rough bone edges should be gently rasped to smoothness.

11. Use a Gighli saw to severe the palate. If possible, the saw cuts only the palate and not the skin of the nasal vestibule. Thus, the saw is threaded inferior to the skin of the nasal vestibule into the nasal chamber and directed posteriorly before being pulled into the mouth. The palate can be severed a little easier with the Gigli saw than by the mallet and osteotome technique. The palatal cut is paramedian to help anchor a prosthesis on the remaining ledge of hard palate and teeth. The ipsilateral or medica incisor may be removd to help with this cut.

12. Sever the maxilla from the nasal bone with a chisel or osteotome until the anterior ethmoidal sinuses are encountered. Then redirect the osteotome to cut

through the ethmoidal sinuses parallel to the dura. A 2-cm broad osteotome is used, cutting just inferior to the ethmoidal vessels and their foramina.

13. Detach the block from the musculature of the pterygoid plates and palatine and sphenoid bones by "walking" a chisel along the lateral side of the antrum until it slips into the pterygopalatine fissure. Several taps, especially near the medial superoposterior part of the antrum, will free the whole block from its attachment. When the block is difficult to remove, the cause is usually incomplete cutting of the osseous abutment of the antrum with the roots of the pterygoid plates and the lateral inferior part of the body of the sphenoid and palatine bones. Redirecting the osteotome medially and superiorly makes it possible to sever this osseous attachment, and the block can then be removed. Alternately, if the pterygoid plates are to be removed, a curved large osteotome is used. The chisel is placed behind the pterygoid plates, and they are transected at their sphenoid origins. At this point after removal of the specimen, the maxillary artery is controlled if bleeding is encountered. Removing the maxilla from the pterygoid region is performed last to avoid the predicament of a bleeding maxillary artery with the specimen still anchored by other bony attachments.

14. Remove the remaining ethmoidal cellular walls carefully with the Mosher biting forceps. The frontal sinus can be opened widely and the mucosa removed to decrease moisture in the cavity postoperatively. The sinus cavity can be lined with a skin graft if it is a shallow bulla or filled with fat or muscle and then covered with a skin graft when it is a tall, frontal sinus. The frontal sinus may also be left undisturbed. The anterior face of the sphenoid sinus is opened widely.

15. After the block is removed, excise the mucosa and skeleton of the nasal septum facing into the cavity, in the manner used for submucous resection. Then cover the opposite mucoperichondrium and periosteum with a skin graft to reduce moisture in the cavity postoperatively.

16. Line the entire cavity (cheek, muscles, and orbital bone) with skin graft. Split-thickness skin, 0.018-inch thick, should be taken from the thigh or abdomen. The graft is "pie crusted" to allow drainage and sutured in place.

17. To facilitate eating and talking, wire the patient's upper denture or prosthesis to the lateral part of the remaining frontal bone and secure its opposite side to the contralateral alveolus with wire. Pack the cavity with a continuous strip of gauze moistened with antibiotic ointment. After 10 days the denture and packing are removed. Thereafter, a foam rubber or sea sponge is inserted into the cavity before eating or talking.

    Alternately, the skin graft can be held in place by foam rubber trimmed so that it fits snuggly into the cavity upon expansion. It is cleansed in appropriate sterilizing solution and then impregnated with antibiotic ointment. After 7 to 10 days when the skin graft has healed to the underlying tissues it is gently removed. It may be cleansed in a soap water solution and reinserted as needed until an acrylic obturator is fashioned. The foam sponge technique generally is more comfortable to the patient.

18. When the eye is not being removed with the specimen, the periorbita should be grafted with split-thickness skin. Unless the periorbita is detached, the eye will maintain its position. Reattachment of the medial canthus is performed by suture to the periosteum. Should there be a need, a supporting sling of temporalis muscle fascia or fascia lata can be constructed.

19. Thread a nasogastric tube through the opposite nostril, to be used for temporary feeding purposes.

20. After the skin lining has covered exposed areas, an acrylic obturator prosthesis is fashioned for the patient.

Complications

Bleeding is a common early complication but can be minimized with good packing and ligation of the maxillary and other arteries.

Failure of some of the skin to take in the cavity is to be expected. Complete failure requires secondary grafting, especially if the skin fails to take on the raw side of the cheek flap. Care should be taken not to disturb the skin graft lining the cavity during convalescence on repeated removal and cleaning.

In passing through the cribriform plate the olfactory filaments often drag subarachnoid tissue with them. Thus, a cerebrospinal fluid leak is not an uncommon occurrence in this region. If noted at the time of surgery, a mucosal patch is placed and covered with absorbable gelatin sponge. Gauze packing secures healing in 7 to 10 days. The Mosher forceps cuts cleanly, so it will prevent a tear of the meninges lying superior to the ethmoidal block.

The cavity will desquamate and therefore needs to be cleaned frequently. The patient should be appropriately instructed.

Subtotal Maxillectomy

Indications

The sinus is divided into a supra- and infrastructure by the Ohngren's plane. This plane is defined as running between the medial canthus and angle of the mandible as seen from a lateral view.

If the tumor is confined to the sinus infrastructure or to the medial wall of the maxilla, then partial removal usually is possible without compromising the cancer operation.

A 1.5-cm tumor-free margin on all sides of the specimen should be present. Two main instances occur where subtotal maxillectomy is useful. The first is when the tumor is confined to the antral floor. The other is when the tumor is in the medial wall of the sinus. The latter may occur primarily or in extension from the ethmoid sinuses.

For circumscribed lesions of the maxillary sinus, a subtotal maxillectomy may be appropriate. Usually, this procedure is more appropriate for nonsquamous cell, nonadenoid cystic carcinoma lesions. These two lesions have a propensity to extend beyond the grossly visible limits. Two distinct categories of subtotal maxillectomy are commonly used: the "partial" (inferior) and "medial" maxillectomies.

Surgical Anatomy

In exposure through a degloving incision the infraorbital nerve as well as the parotid duct and orifice should be preserved.

If work proceeds to the medial wall of the maxillary sinus, the nasolacrimal duct presents at the anterosuperior corner.

Much of the dental innervation is in the medial wall of the maxillary sinus. Therefore, postoperative paresthesias and numbness may be temporary or permanent.

Partial Maxillectomy

Surgical Technique

1. A degloving incision is placed high in the gingivobuccal sulcus. Thus, innervation to the cheek proper is left intact while leaving a wide periosteal cuff on the anterior and lateral maxilla.

2. The periosteum is elevated to the infraorbital nerve and into the nasal cavity. The nasal cavity is entered from the gingival side.

3. A palatal incision is placed as for the total maxillectomy. The Gigli saw is used.

4. The anterolateral maxilla is cut with a chisel.

5. A chisel and scissors are used to cut superiorly at the inferior turbinate bone posteriorly, stopping just before the sphenopalatine foramen.

6. A curved chisel is used to separate the maxilla from the pterygoid plates as in the total maxillectomy.

7. The specimen is easily mobilized. Hemostasis is achieved.

8. The ipsilateral sphenoid sinus is opened as well as the adjacent ethmoidal air cells.

Medial Maxillectomy

Surgical Technique

1. A modified Weber-Ferguson incision is used. The superior extent ends medial to the supraorbital neurovascular bundles. A horizontal gingivolabial incision is placed. A "W"-plasty at the lip vermilion helps to prevent scar contracture.

2. The flaps are elevated. Laterally, the anterior face of the maxilla is exposed. The infraorbital nerve is preserved. The medial canthus is mobilized. The lacrimal sac is mobilized away from bone, but the lacrimal apparatus is left intact. The ipsilateral nasal bone and soft tissue are elevated medially after a lateral osteotomy.

3. The anterior and posterir ethmoidal arteries are exposed and ligated with hemostatic clips. These arteries mark the cribriform plate.

4. A wide Caldwell-Luc opening is created.

5. Through the Caldwell-Luc opening, the bone immediately behind the nasolacrimal duct is cut with a sharp Freer elevator or chisel. Working from within the sinus, as well as externally, the bone is cut from the maxillary floor upward posterior to the lacrimal sac to the level of the cribriform plate.

6. A cut is made on the medial orbital floor from the previous cut up to and sparing the infraorbital nerve.

7. A fourth bone cut is made along the floor of the medial wall of the maxillary sinus to the pterygoid bones.

8. The fifth bone cut is placed just inferior to the cribriform.

9. The sixth cut is placed along the floor of the orbit. It begins just medial to the infraorbital nerve and ends at the posterior end of the fifth (cribriform) cut.

10. Lastly, the specimen is freed by placing an angled scissors into the posterior end of the fourth (floor of maxilla) cut and cutting superiorly along the posterior maxillary sinus wall. The most superior extent may, by bimanual finger techniques, fracture-release. Hemostasis is achieved.

11. The medial canthus is sewn to periosteum. The nasal bone is returned to its normal position. The nasal cavity is packed.

12. If tumor extends through the cribriform, a craniofacial resection may be necessary. In this case, the neurosurgical team enters the anterior cranial fossa and the orbital roof bone, and the fovea ethmoidalis and cribriform are accessed. Depending on tumor extent, the entire central anterior cranial fossa and posterior frontal sinus table may be removed. Bilateral medial maxillectomies may be performed.

13. The anterior cranial defect is reconstructed by a "sandwich" graft composed of dura from the anterior cranial table, bone, or cartilage, fascia lata and septal mucosal flap. If the brain/dura is in direct contact with the eye, a solid graft material should be placed between the two to prevent pulastion of the globe (pulsatile exophthalmos).

11. The Ethmoidal Sinuses

External Ethmoidectomy

Indications

Ethmoidectomy converts the many cells of the ethmoidal labyrinth into a single cavity. Its more common indications are acute osteomyelitis of the osseous cellular walls associated with an orbital cellulitis, chronic infection of the mucosa unresponsive to normally adequate antibiotic therapy, or recurrent allergic polyposis with chronic infection and mucocele formation. Neoplasms are a less common reason for doing the operation as a single procedure, but ethmoidectomy is often combined with maxillectomy, since the neoplasm of the antrum often invades the ethmoidal cells.

Ethmoidectomy may also be used as a route to repair a cerebrospinal fluid rhinorrhea, to enter the sphenoidal sinus because of primary pathology in that cavity, to remove in toto or obtain tissue for biopsy of a pituitary tumor presenting in the sphenoidal sinus, or to ablate the pituitary gland because of distant, hormone-dependent disease or neoplasm. External ethmoidectomy is preferred by many surgeons to the intranasal procedure because surgical exposure and landmarks are more directly evident.

Surgical Anatomy

The subcutaneum surrounding the eye is highly vascular, and bleeding from branches of the supratrochlear artery and angular artery and vein can be copious. Thus, if a pathologic process has not eroded bone and is not lying in the subcutaneous tissue, the incision should be made boldly down through the subcutaneous tissue to the bone to gain sufficient depth to provide exposure for clamping the bleeding vessels. Small hacking cuts with the knife do not sufficiently expose tissue for identifying and clamping the vessels.

The periosteum overlying the nasal bone and nasal process of the frontal bone must be sharply incised and then elevated with care from the frontonasal and frontoethmoidal suture lines. When the periorbita is separated from the bone of the lacrimal fossa and the lamina papyracea and is elevated laterally, the trochlea will not be injured, since it will be displaced with the orbit laterally.

All orbital retracting should be done carefully to prevent damage to the globe and its vessels, since blindness might result. It is wise to document the vision, retina, and extraocular motion prior to surgery.

The anterior and posterior ethmoidal vessels are landmarks for the dura of the anterior cranial fossa that lies above their horizontal level. In addition, the posterior artery lies 3 to 8 mm anterior to the optic foramen and nerve.

The middle turbinate is removed in the procedure to permit removal of all ethmoidal cells. Since this structure is a valuable landmark for the cribriform plate, it should be left in place as long as possible.

The olfactory fibers on the medial side of the middle turbinate often carry subarachnoid meninges with them as the fibers penetrate through the cribriform plate. Avulsing this turbinate may cause a cerebrospinal fluid rhinorrhea, which should be treated as soon as it is recognized during surgery (see Complications below).

Surgical Technique

1. External ethmoidectomy is usually performed under general anesthesia. To minimize bleeding from the site of the incision, infiltrate the tissues with an anesthetic containing a vasoconstrictor.

2. Suture the eyelids together, utilizing a Frost stitch of 6-0 silk. The suture is passed through the lid grey lines to coapt the lids. All eyelashes should be everted. Do not shave the eyebrows.

3. Dot outline the Sewall incision with a surgical marker around a thumb lightly placed over the closed eye. If a Killian incision is employed, carry the eyebrow part of the incision only as far laterally as the supraorbital notch and not beyond it, unless later in the procedure it is necessary to add to the surgical exposure.

4. Incise the periosteum overlying the nasal bone, anterior to the lacrimal crest. Extend the incision upward over the nasal process of the frontal bone and continue laterally for 1 cm under the supraorbital bony rim.

5. Elevate the periosteum carefully. Retract the lacrimal sac from its fossa and exert care to prevent separation from the lacrimal duct as it passes into the nose. Unless torn, the periorbita will contain the trochlea, and this structure can be elevated from its position and retracted laterally without damage to it.

6. Elevate the orbital periosteum or periorbita from the lamina papyracea until the anterior ethmoidal artery is encountered. Stretch the artery slightly laterally and then clip, tie, or electrocoagulate it. It is essential that the lateral orbital stump remain clipped or ligated to prevent bleeding into the orbit.

7. Continue to elevate the periorbita inferiorly to the maxillary-ethmoidal suture line. Elevate the periorbita posteriorly until the posterior ethmoidal artery can be noted. It is not necessary to elevate farther than this point. For hemostasis clip the posterior ethmoidal artery but do not divide it.

8. With a gouge or chisel enter the ethmoidal cells medial to the lacrimal fossa. These are agger nasi cells.

9. With a Coakley curette, a Knight or Mosher biting forceps, or a Kerrison rongeur, break down a sufficient number of sinus walls until the interior of the nose or the middle meatus is encountered.

10. Remove the lamina papyracea until the posterior ethmoidal artery is noted. Remove the anterior part of the lacrimal fossa for more surgical exposure. Do not remove bone above the horizontal level of the ethmoidal arteries or below the suture line of the lamina papyracea as it joins the maxilla.

11. The middle turbinate is removed. It can be located by entering the anterior naris with an elevator and lifting the structure superiorly and then scissor cutting it. Sometimes it becomes detached and is removed. Avulsion of the entire turbinate should be avoided to help prevent CSF leaks and anosmia.

12. Convert all cells with any pathologic condition into a single cavity opening into the nose. The cells may be removed through the window created by the removal of the lamina papyracea, or an instrument may be passed up and into the nasal chamber and then, in the view offered through the window of the lamina papyracea, cells or pathological material can be removed.

13. Identify the posterior part of the nasal septum where it abuts the sphenoidal rostrum. By studying the radiographs, determine the extent, size, and position of the posterior ethmoidal cells in relation to the sphenoidal sinus. Place a probe into the sphenoidal sinus ostium; then the posterior ethmoidal cells can better be appreciated. Their intercellular walls and foci of pathology should be removed, and a sphenoidotomy is performed.

14. Examine the frontal sinuses. A diseased frontal sinus may be approached in three ways: A) If the sinus is small, remove the floor, ostium, face, and supraorbital rim and ablate the sinus. B) If the sinus is large, create a Boyden flap under the ipsilateral nasal bone. Then remove the floor of the frontal and the adjacent posterior edge of the nasal bone, clean the sinus well of its disease, and insert the Boyden flap. Also fashion an appropriate length of Portex tube, about 10 cm, insert it into the lumen of the sinus, and anchor its inferior end to the nasal septum with 2-0 nylon for 4 to 6 weeks. This keeps the Boyden flap in place and prevents stenosis as well. C) An osteoplastic flap technique may be contemplated with an ethmoidectomy, but it is best to do the osteoplastic flap first and then the ethmoidectomy. In this way the frontal floor is maintained.

15. Decrease bleeding by tamponading with plain gauze strips (1 x 36 in) moistened with a vasoconstrictor. Use a Bucy-Frazier suction cautery.

16. Reattach the medial canthus to the periosteum.

17. Pack the cavity with a 1 x 36 in gauze impregnated with an antibiotic. Do not exert pressure by packing hard against the orbit. Bring the pack out of the anterior naris. Additional packing is sometimes required, perhaps even a posterior pack to provide something solid in the choana to permit anterior packing in some cases.

18. Close the initial surgical incision in two layers.

19. Remove the pack from the ethmoidal cavity and nasal chamber in 48 to 72 hours.

20. During convalescence and healing of the ethmoidectomy site, mineral oil nose drops and warm saline irrigations will diminish crusting in the cavity.

Complications

Operative

If the duct of the frontal sinus or its ostium is damaged during an ethmoidectomy, the frontal sinus should be opened into the nasal chamber widely, by removing the frontal sinus floor in its medial part. Patency of the sinus into the nose is maintained with a Boyden flap or an obturator.

Those ethmoid bony cellular walls that attach to the fovea ethmoidalis and cribriform plate are removed with a sharp-biting instrument such as a Mosher forceps. This is superior to the Knight forceps, for the latter will not cut cleanly but instead may tear the ethmoid bone as it is being removed. Such a tear may extend, involve the dura that overlies the ethmoidal block, and result in a cerebrospinal fluid rhinorrhea. In general, the ethmoidectomy is done with a Coakley curette.

During surgery the ethmoidal vessels may retract and bleed into the orbital tissues. As a rule this is self-limiting and of no consequence. If a change in globe motion, eye pain of a progressive type, or bulging occurs, an ophthalmologist should be consulted. If unabated progression continues, packing should be removed. A canthotomy is usually not necessary unless marked intraorbital swelling exists.

Blindness may develop after this procedure from injury to the globe, optic nerve, or vessels.

If the dura is exposed, no harm results. If it is torn and a cerebrospinal fluid leak occurs, the patient should be given a large dose of IV ampicillin and an aminoglycoside. The defect should be closed by sutures if possible and the tear backed up with muscle fascia or a mucosal graft from the inferior turbinate. A piece of Gelfoam is placed on top of the graft. In this way, when the pack is removed postoperatively, only the Gelfoam will be removed with the pack, and the graft will remain in place over the meningeal tear. Fibrin glue adhesives may be used. A lumbar cerebellopontine fluid drain can be placed to decompress the cerebrospinal fluid for 3 to 5 days.

If the periorbita is torn, the tear is sutured as soon as it occurs so that fat will not herniate into the wound.

Bleeding can be brisk and considerable in this operative procedure. Transfusion is sometimes required. Proper tamponading and cautery during surgery lessen the bleeding. If this is not effective, pieces of microfibrinous collagen applied to the bleeding areas will arrest hemorrhage.

Postoperative

Orbital swelling usually subsides within several days; elevating the head of the bed 30 to 45° around the clock helps markedly.

Diplopia, if initially present, will usually subside within a week if the superior oblique muscle or its pulley has not been injured.

Intranasal Ethmoidectomy

Indications

Intranasal ethmoidectomy is most commonly done to remove chronic polyposis from the ethmoidal sinuses. Additionally, this approach is used to exenterate ethmoid sinus infection. In combination with the transantral approach, visualization of the ethmoidal area is accentuated as two points of reference are established.

Surgical Anatomy

There are from two to eight anterior ethmoidal cells and one to seven posterior ones. The anterior group lies anterior to the root (basal lamella) or attachment of the middle turbinate to the cribriform plate and lamina papyracea. The posterior group contains large sinuses because the ethmoid bone is wider in its posterior part.

Almost all ethmoidal cells lie medial to the antrum as well as superior to it. The exceptions are those rare cells that wander into the sphenoid during pneumatic expansion.

The posteromost ethmoidal cells may envelop the optic nerve and abut the internal carotid artery. Indeed, dehiscences are not uncommon.

If a skull is examined, note the relationship between the middle turbinate and the anterior bulging cells of the agger nasi. Also consult the coronal cuts of those specimens in the preceding chapters of this book.

Surgical Technique

1. An adequate preoperative hypnotid and analgesic are essential. Use local vasoconstrictive anesthesia with supplemental IV medications for the operation. Injection of the middle turbinate, especially the superior aspects at its attachment, are necessary. The anterior nasal wall and that under the middle turbinate in the area of the ethmoid bulla are further sites for injection. An anesthetic-soaked cottonoid with attached string placed over the sphenopalatine ganglion will give analgesia and serve as a sponge for any blood running posteriorly. Blanching of the mucosa assures the best hemostasis and analgesia.

2. Position the patient's head by putting a towel under the occiput, which will elevate the head. The procedure can be done in a sitting position. Head

position is important, since the level of the cribriform plate must always be kept in mind.

3. After the anesthesia has been accomplished, sever the root of the middle turbinate and remove the first centimeter of this structure.

4. As an aid, mark off 5 cm on a curette so that the instrument and others used will penetrate into the nasal chamber from the anterior nasal spine only for this distance. Initially, the posterior ethmoidal and sphenoidal sinuses will not be reached with the curette. Once the fovea bone plate has been identified, the instrument can be inserted farther into the ethmoidal labyrinth to exenterate the posterior ethmoidal cells and the sphenoidal sinus.

5. Using a Takahashi forceps and Coakley curette, begin to exenterate the cells anterior to the root of the middle turbinate and parallel to the cribriform plate. Pull the curette anteriorly and downward. Remove bits of bone and polyps with the forceps. The level of the fovea ethmoidalis is thus determined.

6. Remove the ethmoidal bulla and its surrounding anterior ethmoidal cells.

7. Help confirm the position of the lamina papyracea by placing the curette intranasally and by placing a finger on the outer side of the lacrimal bone in the inner canthus of the eye. Begin to exenterate the ethmoidal labyrinth from anterior to posterior.

8. Push the flail middle turbinate medially into the airstream to gain surgical exposure into the ethmoidal block of cells. This structure may be removed during the procedure, but it is best to leave it in place as a guide as long as possible.

9. Bleeding can be controlled by tamponade with packs containing a vasoconstrictor. Usually bilateral procedures are performed at the same sitting; therefore, exenteration is performed in partial steps, going from one ethmoidal block to the other.

10. The sphenoidal sinus should now be entered if pathology exists there. See Chapter 13.

11. Pack the same as for external ethmoidectomy.

Complications

Same as for external ethmoidectomy.

12. The Frontal Sinuses

Osteoplastic Flap

History

The osteoplastic flap operative procedure is currently the definitive procedure for managing suppurative disease, osteomas, allergic polyps, or mucoceles of the frontal sinus. It is not a new procedure, since it was employed at the turn of the century but then abandoned because of mismanagement of the nasofrontal duct. In frontal sinus disease, surgeons in the 1890s were faced with two problems as a result of infection: (1) eradicating the disease while preserving cosmesis and (2) establishing an adequate nasofrontal duct. Riedel sought to cure the suppuration by total ablation of the anterior and inferior walls, but the resulting flat forehead deformity prevented a wide acceptance of this surgical procedure.

Killian in 1903 believed that cosmesis would be maintained by leaving the superior orbital rim. The infected tissue could be cleaned fro the sinus by removing and anterior and inferior walls. This was correct but led to recurrence, as the mucosa from the nasofrontal duct grew upward into the cavity that was left, and a mucocele or continued suppuration developed.

In 1914 Lothrop tried to solve the operative stenosis of the nasofrontal duct by enlargement, through removing the posterior root of the nasal bones and the intrasinus septum, converting both frontals into a single cavity and draining them together into the nose. This was partially successful.

Lynch in 1921 proposed that only the floor of the frontal sinus need be removed to gain access to the lumen of the sinus to clean it, and that the frontal duct be managed by enlarging it by an ethmoidectomy. Although this was cosmetically acceptable, the procedure did not permit sufficient surgical cleansing of infected tissue from the sinus lumen. More recurrences developed from this procedure than any other.

Boyden developed a flap in 1952, later improved by Baron, to line the nasofrontal duct to prevent stenosis. The flap was based at the cribriform plate, near the anterior part of the nasal septum at the root of the nose. It was elevated from the mucous membrane from the underside of the ipsilateral nasal bone and swung upward. This procedure had little time to be tested, because of the work of Bergara and Itoiz in 1951.

These two Argentinians reported in that year an experimental study of the behaviour of fat in the dog's frontal sinus, which led the way for dealing with frontal insus pathology primarily. The approach to the sinus was that advocated by the early surgeons, the only difference being the insertion of fat after the nasofrontal duct was obliterated by inverting the mucosa into the duct from the sinus and filling the sinus lumen with fat. The osteoplastic flap and obliteration by fat are now widely used as a surgical procedure.

Indication

Primary disease of the frontal sinus, either unilateral or bilateral, with or without disease of the ethmoidal sinuses is an indication for an osteoplastic flap. The type of disease may be suppurative, polypod degeneration and secondary infection, mucocele, osteoma, or traumatic injury. If prior ethmoid surgery to relieve nasofrontal duct obstruction is unsuccessful, then direct surgery on the frontal sinus is also useful.

Surgical Anatomy

Since the inferior wall of the frontal sinus at the supraorbital rim is thin, it will fracture easily to permit entry into the sinus lumen.

The periosteum overlying the face of the frontal sinus should not be stripped from the anterior wall of the sinus, since it provides both a hinge during the fracture of the anterior wall and nutrition postoperatively.

In men, the coronal incision may be invisible in their youth but with balding may become a cosmetic problem.

Surgical Technique

1. Prior to the operation, using the 6-foot Caldwell x-ray view of the frontal sinuses, outline the edges of the sinuses on a piece of exposed x-ray film. The template is made the same size as the sinuses, then cut out along the outline, and sterilized by being placed in benzalkonium chloride or activated glutaraldehyde.

2. Perform the operative procedure with the patient under general anesthesia. Infiltrate this planned incision with a vasoconstrictor-anesthetic solution. Shave the hair from the head in front of the vertical line just anterior to the root of one helix over the top of the head to the opposite helical root.

3. There are two approaches to the frontal sinuses. In tall frontal sinuses, place the incision coronally on the scalp above the hairline. In small sinuses, the incision may be placed either in the eyebrow or just above it. The eyebrow incision does leave a noticeable scar above the eyebrow and between the eyes. When in doubt, use a scalp incision 2 to 3 cm above the hairline.

4. Stand at the head of the table and have the patient placed in a semi-Fowler's position, with the head slightly hyperextended.

5. Make the coronal incision down to, but not through, the periosteum.

6. Neurosurgical hemostatic scalp clips are excellent for providing hemostasis from the edge of the incision. Alternatively, monopolar cautery can be used.

7. Elevate the anterior scalp and forehead flap in the layer external to the periosteum. This is an avascular plane. The supraorbital rims and glabellar area

of the nose become visible. Preserve the supraorbital neurovascular bundle attached or laying in the supraorbital notch.

8. For complete mobility of the flap in its lateral inferior area, extend the scalp incision inferiorly to a point just anterior to the root of the helix. Preserve the superficial temporal arteries.

9. Place the sterilized template over the frontal sinuses, align the orbital rims exactly, and outline the superior and lateral margins of the frontal sinuses with dots using a surgical marking pen.

10. With a sharp knife incise the periosteum down to the bone along the marked line.

11. Slightly elevate and separate the periosteum for 2 to 3 mm on each side of the incision. This facilitates closure by suture later. Do not completely elevate the periosteum from the face of the frontal sinuses as it will be the osteoplastic flaps blood supply.

12. With an oscillating saw or chisel, cut through the bone of the face of the frontal sinuses around and 1 to 2 mm inside the margin of the cavities. Cut the bone on a bevel by directing the chisel or saw inferiorly and posteriorly. The bevel that results will prevent the anterior face from dropping into the lumen of the sinuses when the anterior wall is replaced later. These cuts must extend through the supraorbital rims.

13. Make a horizontal chisel cut in the midlower part of the glabella. The cut is placed at the lower limits of each frontal sinus at its junction with the root of the nose. This is usually 3 to 4 mm above the frontal-nasal suture line. This facilitates the fracture of the inferior all of the frontal sinus.

14. Cut the intersinus septum with a chisel.

15. With a chisel in the beveled cut, pry the anterior wall of the sinuses upward and anteriorly. The bone will fracture through the floor of the sinus. Periosteum and soft tissue hold it snugly inferiorly and give it vascular supply.

16. Remove all pathologic tissue from each sinus lumen. Strip all mucosa from the posterior and anterior walls and remove the intersinus septum. The last vestiges of mucosa are inverted into each frontal ostium and then into the nose. When the pathology is an osteoma, a technical point is to burr into the osteoma to hollow it out and then break off pieces of bone until the pedicle remains.

17. It is imperative to burr the entire lumen of each frontal sinus to remove microscopic vestiges of mucosa that dip into and penetrate the superficial bone of the frontal sinus lumen.

18. A fat graft is taken from the anterior lower left quadrant of the abdominal wall. A horizontal incision is made, and sufficient fat is removed to be able to fill the sinus. The incision is closed in layers and the skin approximated in a cosmetic manner. The wound may require draining.

19. Place the fat into the lumen of the denuded sinus, to fill it completely.

20. After the bone flap is replaced, suture its periosteum to the periosteum of the skull.

21. Replace the forehead and scalp flap and close the skin incision with staples.

22. The wound is drained for 24 to 48 hours by 1/2-inch Penroses, one on either side.

23. The dressing is a light pressure, fluff type. It is left on the head for 24 to 48 hours after the drains are removed.

Additional Technical Points

1. When the eyebrow approach is used, the incision is made just superior to the eyebrow. The eyebrow is not shaved. The incision is beveled to preserve eyebrow follicles. If both frontal sinuses are to be entered from this approach, the eyebrow incisions are connected at the glabella to make a butterfly incision. The supraorbital nerves are usually in the field. If these are cut, anesthesia of the forehead occurs. Often this area will become reinnervated over several months.

2. When pathology is confined to only a single frontal sinus, the chisel cut is made parallel and just lateral to the intersinus septum. The position of the intersinus septum should be drawn on the template. Obliteration is achieved with the intersinus septum intact isolating the two frontal sinuses.

3. If an external ethmoidectomy is to be performed, it is difficult to enter the ethmoidal cells from a coronal approach; a Sewall incision is usually required.

4. If a mucocele has expanded the floor of the frontal sinus, the bone can be pressed back into place with the thumb in a manner similar to removing a dent in a Ping-Pong ball.

5. The dura may be exposed either accidentally by infection or intentionally to inspect its surface. This exposure does not contraindicate using fat to obliterate the sinus cavity.

6. If a fistulous tract extends between the sinus and skin, excise it in a fusiform fashion according to relaxed skin lines. Curettage of the underlying bone is needed until healthy bone is seen.

7. Postoperative periorbital edema resolves quickly after the dressing is removed and the patient becomes ambulatory.

Complications

Postoperatively, blood may accumulate under the scalp flap. This is usually absorbed spontaneously and does not need to be drained.

If recurrent pathology or osteomyelitis develops, subsequent surgical drainage and removal of the infected tissue is needed. The sinus may require ablation by removal of the entire anterior wall and floor. Later, acrylic cranioplasty can be performed to restore forehead contour.

Acrylic Frontal Cranioplasty

Indications

The Riedel procedure may be performed because of a loss of the frontal bone from osteomyelitis, comminuted fracture of the anterior wall of the sinus or fracture of the posterior wall, and concern for future episodes of meningitis. This procedure ablates the frontal sinus completely, since both the floor of the sinus and the anterior wall are removed. After healing, the soft tissue of the forehead becomes adherent to the posterior table of the frontal sinus or any exposed dura. This produces the cosmetic defect of a flattened forehead; also, the eyes are projected more anteriorly than the forehead.

Some months after the Riedel procedure, acrylic is placed under the skin of the forehead to provide satisfactory cosmesis of the brow.

Surgical Technique

1. The anesthetic, incision, forehead, and scalp flap are identical to those in the osteoplastic flap technique. The exception is at the junction of the superior margin of the defect, which is located at the posterior table of the old frontal sinus with the skull. At this point the periosteum is elevated with the forehead flap, exposing the bone of the posterior table or dura. The elevation is carried inferiorly to just above the orbital roof and downward toward the nose.

2. Take care not to tear the scar of the previous procedure and enter the nasal chamber. This is necessary because such a tear will expose the plastic, when it is inserted, to the nasal bacteria. Secondary infection and subsequent rejection are the sequelae.

3. Mix the methylmethacrylate and place it into the defect of the skull. The polymer should be mushy and not too thin, or small particles may enter the bloodstream as emboli. It should be molded and contoured to the shape of the defect. It may be placed over exposed dura.

4. Cool the plastic in situ as it hardens to negate its heat of reaction.

5. After it is sufficiently hard, remove it and perforate it through and through with a dental burr to provide channels for fibroblasts to enter during healing. In such a manner, the acrylic can be anchored.

6. Obtain additional anchoring. If needed, by drilling holes into the adjacent skull at the margins of the plastic and wiring the plastic to the skull at these points.

7. Close the scalp wound in two layers, without draining.

Complications

Entry into the nasal chamber during the dissection will create a channel that will invite infection and rejection of the plastic.

If entry occurs, abandon the procedure, wait for healing to take place in several months, and attempt the procedure again.

Failure to have sufficient plastic in one site can be easily corrected by adding additional plastic. This material adheres to itself, and it is not necessary to redo the entire acrylic mass.

It is important to have sufficient projection in the region of the eyebrows.

Trephination

Indications

During an attack of suppurative sinusitis, if the ostium of the frontal sinus becomes closed and the infection continues within the sinus lumen, an empyema results. Conservative therapy such as antibiotics and decongestants, local nasal sprays, and tampons containing vasoconstrictors directly applied to the anterior part of the middle meatus may not be effective in reducing the headache, fever, and signs of inflammation. In such instances after conservative therapy fails, trephination of the sinus is performed. In patients with a Pott's puffy tumor trephination will establish drainage, but later a definitive surgical procedure should be performed for the chronic osteomyelitis.

Surgical Anatomy

The area of the floor of the frontal sinus can be approached via a small incision under the brow that heals quickly and cosmetically with little scar.

The sinus develops from below upward; therefore, entry into the floor assures entry into the sinus lumen.

The floor of the frontal sinus is the thinnest of all walls and thus the easiest to be perforated for trephination.

The Caldwell and lateral radiographs are excellent for estimating the size and depth of the frontal sinus.

Surgical Technique

1. Inject a local anesthetic into the tissues of the eyelid above the inner canthus under the eyebrow. Suture the eyelids shut for protection of the globe.

2. Make a 1.5-cm incision in the tissues of the upper eyelid, down to the bone under the supraorbital ridge. Preserve the supraorbital neurovascular structures.

3. Incise the periosteum and elevate it from the roof of the orbit under the floor of the frontal sinus.

4. Use a burr or chisel to enter the floor of the frontal sinus.

5. Upon entry, culture for the predominant organism.

6. Irrigate the frontal sinus lumen.

7. Place a rubber catheter (no 10 Fr) into the lumen of the sinus. With sutures sew it in place; lead it laterally above and beyond the external canthus of the eye to the temple and tape it to the skin.

8. Close the original incision in two layers so that the closure holds the catheter in position securely.

9. The catheter serves as a drain and as an irrigation line. Within 24 to 48 hours the warmed saline-irrigating fluid easily passes down the frontal ostium and appears in the nasal chamber. The catheter is removed since the ostium is again patent.

10. When bilateral frontal sinus disease require drainage, enter the contralateral frontal sinus via the intersinus septum or perform a bilateral trephination procedure.

Complications

The incision should be made far enough medially onto the floor of the sinus so that the trochlea of the superior oblique muscle will not be injured.

It is important to enter the frontal sinus far enough anteriorly to avoid injury to any pathologically exposed dura.

13. The Sphenoidal Sinuses

Transethmoidal Sphenoidotomy

Indications

The sphenoidal sinus may be entered to remove primary disease within it, or the sinus may serve as an approach to the pituitary gland. The usual primary diseases are suppuration in the cavity from a chronic sinusitis or a mucocele. Regarding the pituitary gland, it may be the seat of a neoplasm, or it may need to be excised because of a distant tumor or disease that is hormone-dependent.

Surgical Anatomy

The superior and anterior walls of the sphenoidal sinus are its thinnest. The lateral and superior walls are the ones to respect with great care. The inferior wall is the safest. The pituitary gland commonly bulges into the superior wall.

The carotid artery, vidian nerve, and optic nerve commonly cause a ridge on the lateral wall if the sinus pneumatically expands laterally for any distance.

The sinus is commonly very deep in its anteroposterior dimension and often has extensions into the wings and pterygoid plates of the sphenoid bone.

Surgical Technique

The sinus may be approached through the ethmoidal labyrinth after an external ethmoidectomy, or through the nasal septum, or transantrally. An isolated sphenoid sinus pathology may be approached transnasally; however, the visual angle is narrow.

External Ethmoidectomy Approach

1. After an ethmoidectomy, the face of the sphenoidal sinus is exposed in the depth of the surgical wound.

2. To mark the location of the ostium, "walk" a suction tube on the nasal septum posteriorly until the sphenoidal rostrum is reached. About 2 mm laterally locate the ostium of the sphenoidal sinus.

3. Remove the mucosa from the face of the sinus by dissecting it from above downward. As the mucosa is retracted inferiorly, the sphenopalatine arterial branch to the nasal septum is retracted with the mucosa and removed from the field without damage to it. If it is distinctly seen, the artery may be cauterized bipolarly.

4. Enter the sinus through its bony face, just inferior to the ostium.

5. Enlarge the opening with a rongeur and curettes. When disease is encountered, remove the entire face and floor of the sinus. Clean the cavity by curettement. If the mucosa that covered the rostrum is available, push it into the sinus; hold it in place with a pack.

6. Pack the nasal cavity and ethmoidectomy cavity and bring the pack out the anterior nares.

Transseptal Sphenoidotomy

Indication

This route may be chosen for surgery on the sphenoidal sinus or the pituitary gland instead of a transethmoid one.

Surgical Anatomy

The posterosuperior portion of the nasal septum abuts the sphenoidal rostrum. Thus, the vomer of the nasal septum guides the operator directly to the sphenoidal air sinus.

The face of the sphenoidal sinus contains the ostium, which is an excellent landmark. This wall is usually quite thin to permit easy entrance into the sphenoidal sinus cavity.

The sphenoidal intersinus septum may course laterally in its posterior parts and actually anchor on the lateral wall. The carotid artery may be in proximity to this anchoring point.

Surgical Technique

1. General anesthesia is preferred but is supplemented by injection of an anesthetic with a vasoconstrictor into the tissues of the upper lip and septum. Epinephrine is applied topically to the mucous membrane of the nose.

2. Elevate the head so the bleeding will not gravitate into the depth of the surgical wound.

3. Frost stitches may be placed intro the eyelids to protect the globe.

4. A piece of fascia and/or muscle should be obtained from the abdomen or the upper thigh if pituitary surgery is performed.

5. Suture the drapes in place so that towel clips are not an impediment on the x-ray film should orientation x-rays be needed during the surgical procedure.

6. A sublabial incision is usually employed. Make an incision 2 cm on each side of the midline frenulum of the upper lip with a hot electrosurgical knife.

7. Elevate the tissues to enter the piriform aperture of the nose adjacent to the nasal spine of the nasal septum and elevate the nasal mucosa from the floor of each nasal chamber.

8. Do not fracture the nasal spine until all of the mucoperiosteum is removed from the floor of each nasal chamber. The fracture the nasal spine and the upper portion of the piriform crest bilaterally to gain full exposure into the dissected area of the nasal septum.

9. Displace the septyal cartilage and bone to one side and uncover the bony face of the sphenoidal sinus by pushing the mucosa that covers it laterally.

10. Locate the natural ostium of the sphenoid sinus for identification.

11. Remove the osseous face of the sphenoidal air sinus with a curette. If it is thick, drill it as needed. Convert both sinuses into a single cavity for larger surgical exposure.

12. Whenever a mass is encountered in the sphenoidal sinus it is wise to insert a needle into it to see whether it is a vascular structure before instrumenting it further. In the case of a mucocele or disease involving the sphenoidal air sinus, it is wise not to curette the lateral wall or the posterior one but remove the tissue as gingerly as possible to prevent a complication from damaging vascular or neural structures. Whenever a pituitary lesion is removed it is wise to fill the cavity with fat, fascia, or muscle, depending on the surgeon's preference.

13. Replace the tissues in the nasal chamber and hold them in place by packing for 48 hours.

14. Suture the original incision in the mucosa of the upper lip with chromic sutures.

Complications

The nasal septal branch of the sphenopalatine artery may be accidentally cut during elevation of the mucosa. If this occurs, the artery must be either clipped, tied, or electrocoagulated.

Injuries to the optic nerve generally have no therapy. If the internal carotid artery is injured immediate packing is performed. Intracranial bleeding may not be prevented however. An arteriograpm with balloon embolization therafter may be useful.

If the dura is torn during the procedure, it is repaired by packing the tear with fascia and muscle. The thigh usually serves as the donor site, and a piece of fascia lata is obtained and placed over the leak. A piece of muscle is then placed over the fascia. The mucosa that covered the face of the sphenoidal sinus is placed over the muscle. A pack is placed over the mucosa for 48 hours. A lumbar drain is placed for 3 to 5 days to decompress the cerebrospinal fluid. The patient is allowed to convalesce in the sitting position for 2 weeks. Antibiotics are used, and the patient is watched for signs of meningitis.

Transnasal Sphenoidotomy

1. Inject the septum and middle turbinate with a vasoconstrictive anesthetic. Blanching should occur. This will prevent any blood from entering the field should these structures be abraded.

2. The natural ostium may be visible behind the middle or superior turbinate 2 mm from the midline. Most often it is not visible.

3. From the posterior tip of the middle turbinate, starting at an upwards angle of 25° the sinus is entered by "walking" up the anterior face. Gentle controlled pressure 1 to 2 mm lateral to the septum is used.

4. After entering the sinus a Kerrison rongeur or curet is used to open the face in an inferior direction. Remove any polypoid disease with caution. Wide marsupialization of the sinus is the objective.

Part Four

Surgical Procedures on the Paranasal Sinuses - Endoscopic Techniques

14. Anatomy Specific to Endoscopy

It is important to know the exact anatomy of the paranasal sinuses in both the normal anatomic and the pathologically changed nose. Secure anatomic orientation intraoperatively is indispensable in ensuring that disease is eradicated and complications are minimized. Indeed, nasal anatomy encompasses a wide spectrum ranging from anatomic variations through chronic inflammation to malignant tumors (Table 14-1). The sinuses are surrounded by delicate and vital structures. Transgressing sinus boundaries may lead to complications ranging from nasolacrimal duct obstruction to carotid damage, meningitis, and death.

In envisioning the extent of lesions one must remember that the scale of the lateral nasal wall is small. If the ethmoid complex is viewed in comparison to a finger, one notices that the volume is approximately that of the last two phalanges. It is remarkable that pathologic biology starting within a volume of this small size has such a potential for causing morbidity and even mortality.

While operating, the surgeon must be constantly oriented in three dimensions. When observing a structure, one must keep in mind not only the surface of that structure but also what lies beneath. One's knowledge of the relationships to surrounding anatomic structures from a microscopic to a gross perspective must be secure. Eventually, the mind can visualize the three-dimensional anatomy that awaits beneath the nasal mucosal surface. With the mental picture, pinpoint accuracy can be achieved despite pathologic destruction of landmarks. The surgeon works from the known to the unknown.

Initially, the lateral nasal wall is best seen in a perspective from the meatus communis. The four turbinate bones, or concha, are seen. The middle, superior, and supreme turbinates are also known as ethmoturbinates because they arise from the ethmoid bone. The three ethmoidoturbinates arise from a common conchal lamina superiorly. The inferior turbinate is a bone unto itself. The supreme turbinate is not a constant finding. Each turbinate has a neck, head, and body. Sometimes at the turbinate head there is an enlargement known as a lobule of Killian or operculum of Zuckerkandl. The lateroinferior border may be markedly scrolled laterally, giving rise to a space known as the conchal sinus. If very deep, this conchal sinus may give the appearance of a bulbous medial convexity of the middle turbinate known as a tuberculum ethmoidale anticum. A similar situation is mimicked if the superior turbinate arises from the lateral aspect of the middle turbinate. Underneath each turbinate is an opening for sinus effluent known as a meatus. There is a sphenoethmoidal recess at the posterior-superomost portion of the nasal cavity, behind the superior or, if present, the supreme turbinate.

Sometimes an air cell may lie within the middle turbinate. This is called a conchal cell. If the middle turbinate is widely pneumatized and bulbous, it is known as a concha bullosa. Sometimes, during its growth period, a posterior air cell may insinuate itself between the medial and lateral lamellae of the middle turbinate. This is an interlamellar cell.

Along the roof of the nasal cavity, medial to the conchal lamina, is the cribriform plate. The mucosa in this area contains numerus olfactory nerve endings. Removal of this mucosa may avulse these nerves through the cribriform and give rise to a CSF communication. More laterally, between the conchal lamina and the lamina papyracea, is the fovea ethmoidalis. Removal of mucosa in this area will not lead to CSF communications.

After stripping away the turbinate bones and the ethmoidal air cells one sees the skeletal framework of the lateral nasal wall. Of note is that each turbinate originates from a basal or ground lamella; the terms "grand" or "grund" lamella are used interchangeably. These lamellae are the anchoring structures of the turbinates on the lateral nasal wall and fovea ethmoidalis.

Beneath the apex of the inferior turbinate lamina is the opening of the nasolacrimal duct. It may have a small membranous fold known as the valve of Hasner within it.

Often, the superomost anchoring points of the middle and superior turbinate laminae mark the landmarks for the anterior and posterior ethmoidal arteries, respectively. The ground lamella of the middle turbinate marks the posterior boundary of the ethmoid bulla cell. Of additional note is that there may or may not be air cells between the roof of the ethmoid bulla and the fovea ethmoidalis. However, the lateral most aspect of the ethmoid bulla is the lamina papyracea of the orbit. The basal lamina of the middle turbinate clearly demarcates the anterior from the posterior ethmoidal air cells. Its exact course through the ethmoidal labyrinth varies from person to person. Indeed, each person's ethmoidal labyrinth is as unique as his or her fingerprints. Nevertheless, the basic landmarks remain the same.

The bony lateral wall contains a large bony defect which is the maxillary hiatus. This is the opening into the antrum of Highmore, or maxillary sinus. Two small tubercles are seen at the inferior border of the hiatus maxillaris; anteriorly the lacrimal tubercle and posteriorly the ethmoidal, or uncinate, tubercle. These are part of the inferior turbinate bone. At the anterior edge of the hiatus maxillaris, the bone is slightly thickened; this is the lunula maxillaris. The superior portion of the lunula is made of lacrimal bone, the middle and major portion is derived from maxillary bone, and inferiorly the inferior turbinate may contribute. The significance of the lunula is that it may be the only barrier before reaching the lacrimal duct when approaching posteriorly. Thus, back-biting forceps may sense a slight thickening of the bone when enlarging the maxillary ostium. This resistance may also be due to the decreased leverage of the forceps upon the bony duct itself.

Anterior to the mucosal ridge formed by the uncinate process lies the lacrimal duct. This duct is anterior to the forward-most limits of the middle turbinates. The anterior and posterior ethmoidal arteries can be seen at the junction of the intracranial contents superiorly and the ethmoidal air cells inferiorly. These arteries mark the cribriform plate. Occasionally, there are three ethmoidal arteries. The posteromost ethmoidal artery is between 3 and 8 mm from the optic nerve canal.

In anatomic dissection, the ophthalmic artery is seen to run inferior and medial to the optic nerve; after a short course it gives off the posterior and anterior ethmoidal arteries. Usually the anterior ethmoidal artery is the larger of the two. These two arteries course across the fovea ethmoidalis giving off branches to help supply blood to the ethmoidal air cells and the septum. Occasionally, three arteries are present.

Examination of the lateral nasal wall with only the turbinate bones removed reveals the uncinate process. In lower animals, the uncinate process and its origin, the agger nasi cells, form a turbinate complex known as the nasoturbinale. In humans this is rudimentary, however. The larger ethmoid bulla or torus lateralis can be seen just posterosuperior to the uncinate process. Its large face is also known as the promontory, or protuberance. Between the uncinate process and the concha bullosa is the hiatus semilunaris inferioris of Grünwald. This is the entrance into the funnel-shaped infundibulum. Between the ethmoid bulla and the middle turbinate lies a slitlike opening known as the hiatus semilunaris superioris of Grünwald. It opens into the sinus lateralis or suprabullar furrow, which may be a drainage route for some posterior ethmoidal air cells. The infundibulum is the conduit into which the frontal sinus, maxillary sinus, and anterior ethmoidal air cells drain. Its superior border is the recessus terminalis. The entire area lies in the frontal recess of Killian.

It should be noted that the uncinate process diagonally divides the hiatus maxillaris into anterosuperior and posteroinferior fontanelles. These areas are dehiscent of bone and contain only mucous membrane covering. The maxillary sinus ostium lies in the anterior fontanelle. In somewhat more than 10% of persons an accessory opening into the maxillary sinus may be found in the posterior fontanelle.

When the cribriform and the fovea ethmoidalis are viewed from the superior aspect, the lateral nasal wall and ethmoid sinuses progress laterally upon posterior dissection. Continued dissection in this plane of the lamina papyracea would violate the optic nerves.

Further dissection of the fovea ethmoidalis and orbital contents reveals a thin layer of fat between the lamina papyracea and the ocular muscles. This fatty layer may be exposed without problems, but extirpation may give rise to ocular complications. Additionally, if the ethmoidal arteries are violated, they may retract into this fat giving rise to a hematoma.

The posteromost ethmoidal, or postreme, air cell is a triangular structure known as the cell of Onodi. It may wrap itself around the optic nerve. The relation of the sphenoid sinus to the posterior ethmoidal air cells is variable. In general, the sphenoid sinus itself sits medial, inferior, and posterior to the ethmoidal air cells. The sphenoid ostium of Bertini may be seen either medial or directly posterior to the middle turbinate.

Within the sphenoid sinus, the carotid artery lies against the lateral wall. The optic nerve may be in a bony sheath between the sphenoid sinus and the postreme ethmoidal air cell. Inferiorly, along the lateral wall of the sphenoid sinus, may be the maxillary nerve and the Vidian nerve. Dehiscences of any of these structures are not uncommon.

15. Glossary of Endoscopic Sinus Anatomy

Accessory maxillary sinus ostium: In posterior fontanelle. Cilia do not beat toward this opening; only passive drainage can occur.

Agger nasi (From Laing *agger,* eminence): The anteromost air cells of ethmoid; part of the nasoturbinale complex.

Basal lamella (ground, grand, or grund lamella): Each turbinate is attached to the underlying bone by one or more bony plates. After the ethmoturbinales are removed, these basal lamellae divide the ethmoid air cells into distinct drainage groups.

Choanal polyp: A polyp that originates in the maxillary sinus antrum and becomes pedunculated, hanging into the nasal cavity and even the nasopharynx.

Concha bullosa: Condition in which pneumatization within the middle turbinate expands it to a larger than normal size. It may thus mechanically impinge on the middle meatus and may also become infected itself.

Conchal cell: Air cell arising in and contained within the turbinate bone.

Conchal head (operculum of Zuckerkandl, lobules of Killian): Anteromost portion of middle turbinate appearing as a protuberance. The term if qualified may also indicate same relative area of other turbinate bones.

Conchal lamia (from Latin *lamina,* thin plate): The vertical bony plate beginning at the skull base from which the ethmoturbinates are suspended.

Conchal neck: Portion of middle turbinate extending from agger nasi cells toward conchal head.

Conchal plate: see Conchal lamina.

Conchal sinus: see Sinus turbinale.

Cribriform plate (from Latin *cribum,* sieve): Structure at medial aspect of fovea ethmoidalis through which the olfactory nerve fibers and ethmoid arteries enter the nasal cavity.

Double middle concha (Kaufmann concha): A bifid variation caused by a deep sagittal crease.

Ethmoid air cells (from Greek *ethmos,* sieve): The **anterior** cells drain into the middle meatus; they are located anteroinferior to the basal lamina of the middle turbinate. The **posterior** cells drain into the superior meatus or the sphenoethmoidal recess; they lie posterosuperior to the basal lamina of the middle turbinate. See also Postreme ethmoid cell.

Ethmoid bulla (torus lateralis): Large anterior ethmoidal air cell; forms part of posterior margin of hiatus semilunaris inferioris and infundibulum.

Extramural air cells: Pneumatization of bony structures beyond the confines of the ethmoidal bone.

Ethmoturbinale: see Turbinates.

Fontanelles (from French *fontanelle*, spring): "Soft spots" in bony lateral nasal wall composed of mucous membrane only; found in the hiatus of the maxillary sinus; divided into anterosuperior (anterio) and posteroinferior (posterior) fontanelles.

Fovea ethmoidalis (from Latin *fovea*, depression): A distinct depression in the anteromedial skull base that forms the roof for the ethmoidal cells.

Frontal recess (Killian recess): Air space bounded by middle turbinate medially, agger nasi cells anteriorly and laterally, by fovea ethmoidalis and floor of frontal sinus superiorly and by ethmoidal bulla posteriorly.

Grand lamella: (See Basal lamella).

Ground lamella: (See Basal lamella).

Grund lamella: (See Basal lamella).

Halle cells: Extension of ethmoid pneumatization to floor of orbit; may mechanically impinge on maxillary ostium.

Hiatus of maxillary sinus: Area of dehiscent bone forming an opening between the maxillary sinus and nasal cavity; area in which fontanelles and maxillary ostia are found.

Hiatus semilunaris (hiatus of Grünwald): **Superior:** Between ethmoid bulla and middle turbinate; opens into sinus lateralis. **Inferior:** Between uncinate process and ethmoid bulla; opens into infundibulum.

Infundibulum (from Latin for funnel): Area lateral to and into which hiatus semilunaris inferioris opens. Agger nasi, anterior ethmoidal, frontal and maxillary sinus cells drain into this groove.

Interlamellar cell (Grünwald cell): Air cell within the middle turbinate, between its lateral and medial walls, from posterior ethmoidal cells.

Intramural air cells: See Extramural air cells.

Lobule: See Conchal head.

Maxillary lunula: Small curved ledge of bone at the anterior edge of the hiatus maxillaris; part of maxillary bone.

Maxillary ostium: Opens into infundibulum; cilia of maxillary sinus beat toward this opening (in contrast to accessory ostium).

Maxillary process: See Uncinate process.

Maxillary sinus (sinus of Highmore): May have two ostia, of which only the true ostium empties sinus by ciliary propulsion of mucous blanket. Accessory ostium drains sinus passively.

Meatus (Latin *meatus*, path): **Inferior meatus:** Space underneath the inferior turbinate; nasolacrimal duct opens into this space. **Middle meatus:** Space underneath the middle turbinate; anterior ethmoidal cells, agger nasi cells, frontal sinus ostium, ethmoid bulla empty into this space. **Superior meatus:** Space underneath the superior turbinate; many posterior ethmoid air cells empty into it. **Communal meatus:** The nasal cavity.

Nasolacrimal duct (duct of Hyrtl; duct of Taillefer): Empties under inferior turbinate into inferior meatus. Convexity of its bony covering within nasal cavity may be a very protuberant, ridgelike obstacle parallel and anterior to uncinate process prior to entering middle meatus.

Nasoturbinale: Phylogenetic remnant of a conchal apparatus consisting of agger nasi air cells and uncinate process.

Operculum: See Conchal head.

Operculum of Hasner (operculum of nasal lacrimal duct): A mucosal fold at the entrance into the nasolacrimal duct in the inferior meatus.

Paradoxical turbinate: A turbinate with a lengthwise bend opposite to normal and often impinging on middle meatus.

Plica maxillaris: Mucosal fold situated in the anterior hiatus semilunaris inferioris. May impinge on maxillary sinus ostium.

Postreme ethmoid cell (Onodi cell): Posteromost air cell of ethmoid group. Especially noteworthy since it may pneumatize around the optic nerve.

Processus turbinalis: See Uncinate process.

Promontoria: Large, highly visible front face of the ethmoid bulla.

Protuberance: See Promontoria.

Recessus terminalis: Supermost extent of the infundibulum into which the frontal sinus drains.

Rima olfactoria: Area below cribriform which carries olfactory fibers into nose.

Saggital crease: See Double middle concha.

Sinus lateralis (sinus of Grünwald): Air space superomedial to ethmoid bulla and lateral to middle turbinate; entrance is hiatus semilunaris superioris.

Sinus turbinale (conchal sinus): Air space in the concavity of a turbinates curvature.

Sphenoethmoidal recess: Air space bounded laterally by posterior ethmoid cells, anteriorly by superior or supreme turbinate, posteriorly by sphenoid sinus, superiorly by plate. Drainage area of sphenoid sinus and posterior ethmoid air cell.

Sphenoid ostium (ostium of Bertini) (from Greek *Sphen,* wedge): Paired; at the anterosuperior margins of sinus, behind superior turbinate and draining into the sphenoethmoid recess.

Suprabullar furrow: See Sinus lateralis.

Torus lateralis: See Ethmoid bulla.

Tuberculum ethmoidale anticum: If the middle turbinate is markedly scrolled, the medial border may show an eminence (tuberculum) reflecting the depth of the scroll.

Turbinate (from Latin *turbo,* child's toy top): **Middle:** First ethmoturbinale; a part of ethmoid bone. **Inferior:** Separate bone of skull; helps cause air turbulence for temperature and moisture regulation and olfactory perception. **Superior:** second ethmoturbinale. **Supreme:** Third ethmoturbinale; frequently absent.

Turbinate process: See Uncinate process.

Uncinate process (from Latin *uncus,* hook): Bony structure extending inferoposteriorly from the agger nasi cells. Forms prominent anterior border of hiatus semilunaris inferoris. Actual shape is of a quarter helix. Has two "processes" extending from it toward contiguous bones: the turbinate process and the maxillary process. Phylogenetically, once part of the nasoturbinale complex.

16. Anesthesia and Vasoconstriction

It is important to explain the procedure to the patient both before and during the surgery to allay apprehension and maximize cooperation. Ancillary systemic sedation and analgesia are commonly given to avoid general anesthesia. If possible, the anesthesiologist achieves a neuroleptic state (see Chapter 17). Local anesthesia has the additional benefit of not including vasodilatation as with inhalant anesthetics; less bleeding occurs. Since no Valsalva maneuvers are incurred during postoperative awakening and coughing, nasal packing is rarely necessary.

General technique. Preincision vasoconstriction is achieved topically and by injection. Initially, vasoconstrictive topical medications such as epinephrine or cocaine are applied by means of neurosurgical pledgets placed within the nasal cavity, especially toward the middle meatus. Ten minutes are allowed for the drugs to take effect. The pledgets are then removed and a submucosal injection of 2% lidocaine with epinephrine solution 1:100,000 is given. This injection, using a 27- or 30-gauge "long" needle, is not a quick, point-blanching type. Rather, a slow, constant pressure on the syringe perfuses the area and causes broad blanching of the mucosa. Specific areas are targeted, and the amount of solution injected is kept to a minimum. The nasal packs are then reinserted, and a wait of 10 to 15 minutes begins to allow full vasoconstriction. Thereafter, a low-dosage booster injection is given to render the blanched intranasal mucosa white. Patience while waiting for mucosal blanching will be more than compensated for an absence of bleeding, superior visualization, and efficient technique.

This same anesthetic procedure may be used with a wide range of pathologic conditions. After initial surgical landmarks have been removed, further landmarks are uncovered. As new anatomy is exposed in sequential fashion, further submucosal injections are given keeping bleeding and pain sensation to a minimum. Thus, general anesthetics are seldom needed.

For intranasal endoscopic *frontal sinus* technique, an external injection is given superoanterior to the medial canthus. Additionally, the *sphenoid area* is anesthetized by direct injection on the sinus face and around the sphenopalatine ganglion using a 25-gauge spinal needle.

Intraorbital injection of epinephrine around the anterior ethmoidal artery is useful when an inflamed tissue bed can be anticipated. Thus, patients in whom severe polyposis or purulent nasal drainage is seen are candidates for this technique. The anterior ethmoid artery is approximately 1.5 cm posterior to the medial canthus. The medial canthus also marks the plane of the orbital septum. An injection posterior to this plane along the lamina papyracea will diffuse posteriorly to act on the artery. Intraorbital hemorrhage due to a lacerated artery or minor vessels may be avoided by minimal penetration of the intraorbital contents by a thin needle. The 27-gauge needle should enter just posterior to the angular vein and several millimeters above the canthus. The needle is kept close to bone. The infiltration is gentle with 0.5 to 1.0 mL of lidocaine with epinephrine as the agent. After 10 to 15 minutes the artery will be maximally affected.

Ancillary anesthesia at the anterior nasal septum and vestibule can be useful. This area is sometimes touches while manipulating the endoscope and can cause discomfort.

For *trocar techniques*, the anterior face of the maxilla is anesthetized by injection just superior to the proposed entry site. For insertion of a trocar into the frontal sinus, a block of the supraorbital and supratrochlear sensory nerves is employed. An additional injection for blanching is given directly over the incision site. In patients with a mild demeanor, a general anesthetic may be useful.

17: Surgical Technique for Endoscopic Sinusectomy

To ensure the best possible surgical results, control of the patient's condition and the surgical site before, during, and after the procedure is paramount. Small distractions such as blood oozing or awkward posture may crescendo into truly significant obstacles unless they are precluded or promptly attended.

The patient is assisted to the supine position with a "donut" headrest under the occiput. An intravenous line, an oximeter, and a blood pressure cuff are placed. The spectrograph is used to monitor exact breathing cycles and exhaled gas content. The spectrographic readings are sampled from the posterior oral cavity by a plastic catheter affixed to the lip level oxygen-delivering catheter.

The patient is situated so that the head is accessible from both sides. A chair is placed at each side. The endoscopic light source and camera equipment are directly at the head of the bed. The nurse with instrument sets is at the one hip, while the anesthesia team is at the other.

The anesthesiologist achieves a neuroleptic state. The nose is packed with neurosurgical pledgets with string soaked in a topical anesthetic (see Chapter 16). After several minutes the pledgets are removed and the vasoconstrictive local anesthetic is injected by means of a 27- or 30-gauge needle. Gentle, atraumatic, slow perfusion renders the lateral nasal wall nearly avascular.

The surgeon is seated throughout the procedure, on the right to treat the patient's left nasal passageway and vice-versa. When sitting on the patient's right side, the surgeon uses the right hand for instrumentation. When sitting on the left, the surgeon maneuvers the endoscope with the right hand and instruments with the left. No sheath is used over the endoscope. Thus, with a very slight tilt of the patient's head toward the surgeon the endoscope points directly at the targeted sinuses. Excellent visualization of surgical landmarks and knowledge of anatomy are of far greater usefulness than artificial means of "avoiding" structures such as by working in a recurving trajectory on the right nasal passage from the right side. In a similar way, the centimeter-calibrated probe should be an uncommonly used instrument.

During the procedure, soothing classical music is used as background camouflage noise. Instruments are asked for by eponyms or hand signals. Since there is excellent monitoring of the patient's physiologic state, questions related to and by the anesthesia team are minimized.

Surgical Technique

Endoscopic view of the left middle meatus through the endoscope. At the start of an endoscopic procedure landmarks must be used for orientation. All aspects of the surgery must be performed with constant visualization. No "blind" technique is used. Most often, a portion of the middle turbinate, the uncinate process, or nasolacrimal ridge will be visualized. Often, however, portions of the turbinate or the uncinate process are directly covered with or camouflaged by overlying polyps. Indeed, purulent debris and crusting may be present. If this is the case, these obstructions must be suctioned clean and removed mechanically. Exquisite vasoconstrictive mucosal blanching for hemostasis should already be in place at this point.

Endoscopic view of sickle knife incising uncinate process prior to removal. The middle turbinate has been medialized by means of the Freier elevator. To prevent bleeding, care is taken not to violate the mucosa of the middle turbinate. Thus, the uncinate process is well visualized. The origin of the uncinate process is within the agger nasi cells of the ethmoid complex. Thus, the superior portion of the incision is begun first. A downward stroke is used to help prevent accidental upward penetration of the nasal roof. Mucosa as well as paper-thin uncinate bone is included in this incision. A semilunar shape results. The anterior boundary of this incision is just past the posterior border of the nasal lacrimal duct. The nasal lacrimal duct is identified as the ridge just anterior to the uncinate process.

Endoscopic view of Takahashi forceps removing the uncinate process. After the mucosa and bone of the uncinate process have been incised, the uncinate is removed. This is done using a forceps under direct vision. Often polypoid tissue is seen behind the uncinate process covering the ethmoid bulla. Polypoid tissue has no bony consistency; its soft texture as well as its typical appearance helps identify it. Ultimately, the goal at this point is to identify the ethmoid bulla. Sometimes the 45° upbiting forceps is used to remove several of the agger nasi cells at this point to help clarify the view of the ethmoid bulla. To prevent bleeding, caution is used not to tear mucosal attachments, in a stripping fashion, as the uncinate is removed. Rarely, bipolar cautery may be needed to achieve hemostasis.

Endoscopic view of straight Takahashi forceps removing mucosa from the ethmoid bulla. After the face of the ethmoid bulla is identified, its promontorium is targeted. The straight forceps is used to remove mucosa from its front surface. After bone has been identified, it is gently eggshelled and the removed. A large opening is created so the internal portions of the ethmoid bulla can be visualized. Indeed, polypoid tissue may exude from this bulla. Eventually, the surgeons' technique may progress so that a single bite will open the entire ethmoid bulla.

Endoscopic view of the extirpated ethmoid bulla. In ethmoidal surgery, the bony landmarks are paramount. The posterior wall of the ethmoid bulla is the bony nasal lamina. Violating this lamina will penetrate into the posterior ethmoidal cells. The lamina papyracea is paper thin. As work proceeds posteriorly, additional anesthetic-vasoconstrictive agent can be injected. The more posterosuperior portions of middle turbinate, and the basal lamina are mucosal areas that may benefit from primary or re-blanching injection. The lateral wall of the ethmoid bulla is the lamina papyracea.

Side view of the dissection to this point. The ethmoid bulla can be seen to be opened and cleared of mucosal debris. Its posterior margin is the basal lamina. The infundibulum with the maxillary sinus ostium can be seen. Superiorly, in the infundibulum, are the recessus terminalis and the frontal sinus ostium. Note that the mucosal edges of the removed uncinate process form a curvilinear edge at the anterior boundary of the infundibulum. Indeed, the overhanging edges of the posterior uncinate process create the anterior lip of the hiatus semilunaris inferioris. Removing the uncinate process thus partially unroofs and opens the infundibulum.

Endoscopic view of the 45° upbiting forceps removing the agger nasi cells. The superior portions of the infundibulum may be blocked by polypoid tissue and infection within the agger nasi cells. In turn, this may obstruct the nasofrontal duct. Additionally, to visualize the nasofrontal duct adequately it is most often necessary to widely remove the agger nasi cells. This allows for good air circulation within the superior portions of the nasal vault and frontal recess. The roof of the agger nasi cells abuts the frontal sinus at the level of the cribriform plate. However, the superior wall of the agger nasi cells is not violated until the frontal sinus ostium has been opened. The agger nasi cells share a common lateral wall with the lacrimal sac.

Upon removal of the agger nasi cells the skull base comes into clear view. The frontal sinus orifice may be seen at the apex of the recessus terminalis. Sometimes a polyp can be seen blocking it. Just 1 to 3 mm behind the frontal sinus ostium is the anterior ethmoidal artery. It courses diagonally across the operative field from lateroposterior to anteromedial. Just behind it, the superiormost ethmoidal cell can be seen touching the skull base. In general, the skull base bone is a more yellowish color than the walls of the ethmoidal cells. Additionally, it is quite firm compared with the ethmoidal cells. Nevertheless, polyps may erode bone. Thus, excessive or absent resistance encountered in any bony removal at this point should be verified by checking nearby landmarks. The basal lamina of the middle turbinate can be seen at the posteriormost portion of the ethmoid bulla extending superiorly. In general, a 70° angle telescope gives a good wide angle view of this area. It takes some time in working with a fisheye view for the surgeon to coordinate eye-hand movements.

70° angle telescopic view of the anterior skull base. The osseous boundaries of the frontal sinus ostium can be verified by palpation by using a probe. All polyps should be removed to view the ostium, which can be enlarged under direct vision. A curved Kerrison type punch forceps is introduced into the field and guided toward the frontal sinus ostium. The objective is to open the anterior portion of this ostium. Posteriorly, the ostium may abut the posterior table of the frontal sinus. Consequently, enlargement posteriorly may violate the cranial contents. Additionally, circumferential deepithelialization should be avoided to prevent scar contracture and ostium closure.

70° telescopic view of frontal sinus ostium. The Kerrison type punch rongeur is introduced into the frontal sinus ostium, and bites are taken from anteriorly and anterolaterally. The bone should be bitten cleanly and not grasped with a torquing motion. After the ostium has been enlarged to 5 to 10 mm, the remainder of the contents from the frontal sinus begin to show. At this point, the thin double-spoon angled forceps may be used under direct visualization to remove polypoid tissue from the frontal sinus. If the patient is under local anesthesia, an external injection is placed anterosuperior to the medial canthus of the eye. This will numb the area and no discomfort will be felt. Additionally, suction-aspiration of sinus contents may be of use.

70° telescopic view of enlarged frontal sinus ostium. The convex posterior table of the frontal sinus is visualized. If mucosal bleeding is encountered, a temporary gauze strip packing with topical epinephrine is applied while work is started on the contralateral side. If minor oozing continues at the end of the procedure, a gauze strip pack impregnated with a water soluble antibiotic agent is applied for 48 to 72 hours.

A 30° or 70° angle telescope is used to visualize the superior portions of the ethmoid bulla. If there is an air cell between the ethmoid bulla and skull base it may be removed. The mucosa is stripped from the bone. The forceps are used to eggshell the bone, which is paper-thin. In distinction, the fovea ethmoidalis is thicker and usually a more distinct bone-yellow color. Polypoid disease can erode the fovea, however. The thin bone is removed and the underlying mucosa is then entered. Simultaneous visualization of the skull base at the frontal recess is most helpful as a landmark. The superiormost ethmoid air cells are removed. Above these air cells is the fovea ethmoidalis. The lateralmost bony wall is the lamina papyracea of the orbit.

30° endoscopic view of the ethmoid bulla with instrumentation into the posterior air cells. The posterior wall of the ethmoid bulla, the lamina basalis, is the division between the anterior and posterior ethmoidal air cells. Penetration of this wall begins an extirpation of the posterior ethmoid air cells. Initially, the bone is eggshelled with a straight Takahashi-type forceps. Thereafter, the bone is removed and the underlying mucosa is opened with a forceps. If ethmoid disease has been confined to the anterior air cells, the posterior cells will immediately show evidence of aeration and not be infected. Panethmoiditis, however, will present with infection and polypoid mucosal tissue within these posterior air cells. Indeed, polyps may fall into the field. The polyps are removed. Preoperative radiologic imaging helps delineate disease extent.

30° endoscopic view of the posterior ethmoid air cells. When the basal lamina is opened, more than one posterior ethmoidal air cell may be encountered. The mucosa is removed from all of these air cells and the bony partitions between them are also removed. The medial wall of the ethmoid bulla is a landmark for the lamina papyracea. This plane of dissection along the lamina papyracea is continued into the posterior ethmoidal air cells. Superiorly, the fovea is followed posteriorly as a landmark.

Side view of the ethmoid bulla and open posterior ethmoidal air cells. Note that the lamina basalis has been penetrated. The next step will be to remove the walls between the posterior ethmoidal cells. The skull base of the frontal recess is followed posteriorly. The skull base will gently slope inferiorly as it progresses posteriorly. Dissection must follow this curvature to avoid intracranial penetration.

View of the middle meatus and maxillary sinus ostium. The true ostium is visualized with the 30° or 70° endoscope. Often polypoid mucosa and purulent debris from the maxillary sinus ostium flow into the field. Sometimes it is easiest to locate the ostium initially by using a malleable probe. Gentle ballotement in the area will reveal the opening. The backbiting forceps are placed into the ostium. The anterior limit of the dissection is the nasolacrimal duct with its thin bony covering. The 45° forceps are useful for posterior enlargement and removal of polypoid debris. If no sinus ostium is found, a 45° forceps is used to palpate the mobile mucosa of the hiatus maxillaris. In this soft fontanelle area, perforation into the maxillary sinus can proceed; the sinus is perforated half the distance posteriorly along the superior border of the inferior turbinate. A 1 cm by 0.7 cm ostium is created in the hiatus maxillaris. The major precaution is that the lacrimal duct not be violated. The bony ridge covering the lacrimal duct should be visualized through the endoscope. Any increased resistance encountered on backbiting should be respected and not bitten into. If an accessory ostium is present, it should be included in the neo-ostium.

Endoscopic view of completed maxillary sinus neo-ostium. The enlarged maxillary sinus ostium allows visualization into the maxillary sinus itself. A right angle forceps or suction may enter the sinus to clean its contents. A 70° endoscope allows good visualization of the posterior two-thirds of this sinus cavity. Once this ostium is completed, the mucosa will heal and the ciliary flow will be toward the neo-ostium. Thus, a superior nasal antral window at the site of the natural ostium has an advantage over an inferior nasoantral window along the floor of the nose. Trocarization of the maxillary face can enhance visualization.

After removal of the initial row of posterior air cells, the remaining posterior ethmoid labyrinth may be extirpated. The dissection proceeds from medial to lateral. The posterior portion of the middle turbinate is removed in toto. Alternatively, its small attachment may be left as a landmark. The face of the sphenoid sinus is visualized. The sphenoid face may be opened so that its lateral wall serve as a landmark. The ethmoid fovea can be traced from anterior to posterior or posterior to anterior with this exposure. The skull base curves postero-inferiorly at approximately 15°. This curvature is seen with the endoscope and should be respected. Indeed, one area of possible intracranial penetration is at the ethmoidal roof just anterior to the sphenoid. Posterolaterally, the ethmoidal cells may pneumatize around the orbital apex. The postreme cell (Onodi cell) may envelope the optic nerve. Usually, this cell is not opened unless pus is seen draining from it. The axial CT scan can help identify the position of the postreme air cell in relation to the optic nerve and sphenoid sinus.

70° endoscopic view of the extirpated posteriormost ethmoidal air cells and sphenoid sinus ostium. After the posteriormost ethmoidal air cells have been removed, the lateral portion of the middle turbinate is often loosely attached by its tip. This allows a "window" by which to view the sphenoid face. Sometimes the sphenoid ostium may be seen superiorly. Leaving the attachment of the middle turbinate not only provides a landmark but helps prevent a flail turbinate from becoming attached to the lateral wall by synechiae. Alternatively, if the posterior cells are not removed, the posterior third of the middle turbinate may be removed to improve direct anterior visualization of the sphenoid face. Later removal of posterior air cells in a posterior-to-anterior approach may also be used.

Endoscopic view of sphenoid through extirpated ethmoidal labyrinth. The anterior face of the sphenoid is usually adequately seen after removal of the posterior air cells. If not, the posterior third of the middle turbinate can be removed. The sphenoid ostium is initially enlarged in an inferomedial direction. The entire face may be removed.

Endoscopic view of the left sphenoid ostium. Attempting to open into the sphenoid ostium by direct access from medial to the middle turbinate is unlikely. The upper nasal vault is extremely narrow. Thus, the forceps cannot penetrate to the sphenoid sinus ostium directly. Indeed, the ostium is usually several millimeters lateral to the septum and may be directly behind the superior turbinate.

Endoscopic view of the sphenoid face. The sphenoid face may need to be opened. Dissection is continued inferiorly and medially to enlarge the ostium. Most often, the ostium cannot be seen, and an area is targeted at a 30° angle upward from the posteriormost tip of the middle turbinate and medial to it. This would also be approximately 1 cm superior to the choanal opening. After removal of mucous membrane, the face of the sphenoid sinus is eggshelled. A small Kerrison type punch is used to remove the anterior face of the sphenoid sinus.

Extirpation of polypoid mucosa within the sphenoid sinus is accomplished by beginning inferomedially. Gentle palpation for underlying bony structures as a guide to the inner wall of the sphenoid sinus is paramount. Dehiscence of carotid arteries in the lateral wall occurs in a significant number of patients. The pituitary gland's intracranial contents are covered by bone on the posterosuperior wall. Thus, extensive extirpation in the lateral- and posteriormost aspects of the sphenoid sinus walls is usually avoided unless a biopsy is needed.

18: Special Surgical Circumstances

Concha Bullosa

Endoscopic view of the concha bullosa. A variation of middle turbinate anatomy is the concha bullosa. In this variation, the middle turbinate itself is highly pneumatized and very bulbous. This bulbosity may obstruct the middle meatus. For this reason, the lateral wall of the middle turbinate is removed to allow aeration of the middle meatus and to prevent obstruction.

Endoscopic view of the concha bullosa incision. A sickle knife is used to make the initial incision into the concha bullosa. The hollowness of the aerated turbinate is palpable. Both mucosa and thin bone are incised. The cut proceeds from superior to inferior to help prevent upward accidental penetration of the roof. Only the lateral lamella of the middle turbinate is removed using a Takahashi type forceps.

Endoscopic view of corrected concha bullosa. The lateral lamella has been removed and the pneumatized inner portion of the turbinate is seen. The mucosa from inside the medial lamella is left intact to help prevent excessive scar formation and synechiae. The medial lamella has the olfactory fibers running in its mucosa and should be preserved. Torque should not be exerted upon the lamella because CSF leakage can occur at the attachment of the lamina conchalis to the skull base.

Halle Cells

Cross-sectional view of Halle cells. Extramural extension of the ethmoidal labyrinth onto the floor of the orbit may impinge on the maxillary sinus ostium. These cells are known as Halle cells. Failure to recognize their presence may yield incomplete results at the time of superior nasal antrostomy. Usually, these cells are visualized on CT scan coronal sections.

Cross-sectional view of corrected Halle air cells. After resection of the ethmoidal labyrinth and nasal antral window, the Halle cells are entered and extirpated. Thus, a wide nasoantral window results.

Paradoxical Turbinate

The middle turbinate may be found to bend in the reverse direction from usual. This may lead to impingement of the middle meatus and thus to sinusitis. The turbinate must be distanced from the middle meatus. Preferably the offending bone is resected in a submucosal fashion preserving the medial olfactory fiber-carrying mucosa. Other techniques such as crushing the affected part of the turbinate with a straight forceps to cause morselization and a flail texture or amputation of the offending inferior half of the turbinate may be useful. The superior half contains the most olfactory fibers and is left intact.

Synechiae

In the postoperative period synechiae may form between the middle or lower turbinates and the lateral nasal wall. Obstruction of sinus neo-ostia or even the nasofrontal duct may occur.

Initial prevention occurs by not abrading the middle turbinate mucosa. The turbinate may be medialized using the blunt end of a Freier elevator. If a concha bullosa exists, the mucosa on the inner surface of the medial lamella should be preserved to promote fast epithelialization of the cut edges. Gelatin foam sponge packing of the surgically treated ethmoid labyrinth cavity should be avoided; the packing is incorporated into the healing process and acts as a bridge between the turbinate and lateral wall.

At the first postoperative office visits, thorough cleansing of the blood clots and crusts helps prevent granulation tissue formation and expedites epithelialization. Also, blood clots are removed to prevent "bridging." Meticulous observation and care of the freshly operated area will help prevent synechiae.

Sometimes, despite good care, synechiae may form. Also, new patients may present with sequelae of earlier surgery. Mature scar-tissue synechiae must be dealt with if they impinge on sinus aeration and cause sinusitis.

Dacryocystorhinostomy

If the lacrimal sac or nasolacrimal duct is violated and becomes stenotic or is removed, a dacryocystorhinostomy may be very useful. Conventional techniques use an external facial incision. An endoscopic intranasal approach may be used instead.

Initially, the lacrimal duct contour is visualized anterior to the middle turbinate and uncinate process. The mucosa is removed from this area and also from the external contours of the agger nasi air cells. A fiberoptic light source may be used to help identify the sac. It is gently pressed into the sac tissue bed from the outside. Caution is used not to allow the probe to overheat the external tissues. Thereafter, if prominent, the agger nasi cells that share a common wall with the sac are removed down to the lamina papyracea of the orbit. Next, the bone is removed from over the sac and duct in an eggshell fashion or by dissecting between the bone and soft tissue and nipping with a bone forceps. The removed portion of bone should be approximately 1.5 cm wide.

After the sac has been identified, a lacrimal probe is placed through the puncta into the sac, and location and dimensions are confirmed by ballotement.

The sickle knife is used to incise the sac. A forceps is used to widen the defect by removal of medial sac wall. A Silastic Crawford-style bicanalicular stent is left in place for at least 3 months. The endoscope can be used for postoperative nasal cleansing.

Trocar Techniques

For access to the maxillary, frontal, and sphenoid sinuses through their anterior faces, the trocar may be used. In general, however, other techniques usually suffice. The maxillary sinus is most often approached through a neo-ostium in the middle meatus; the frontal sinus through the frontal recess and nasofrontal duct; and the sphenoid sinus by multiple-layer opening of the face. Occasionally, trocar confirmatory or guidance views are very helpful during work on the sinuses.

Anesthesia is by regional block with local vasoconstrictive injection at the site of proposed trocar penetration (see Chapter 16). A brief general anesthesia is useful if trocar usage is planned in patients with a mild demeanor.

Maxillary sinus trocar techniques. The canine fossa is targeted, in similar fashion, to the Caldwell-Luc approach, for access to the sinus. Gentle but firm rotary motion on the sharp point quickly pushes the trocar into the sinus. Immediately after the bone has been transgressed, the trocar obturator is removed and a telescope is placed through the sleeve to confirm position. In adults, whose maxillary sinus floor is level with the floor of the nose, the inferior meatus approach can be used. Infrequently it is necessary to infracture the inferior turbinate to gain access. High under the turbinate the nasolacrimal duct empties into the inferior meatus. The nasolacrimal duct is not disturbed. Gentle rotary pressure is used to penetrate into the sinus. After the trocar sleeve is in place as a porta, the endoscope, suction, or optical forceps may be used. Generally, the small size of the forceps cup tip precludes major work through the trocar sleeve.

Trocar endoscopic view of the left maxillary sinus medial wall. When the sinus is entered with a trocar, a 70° optic gives the best view. The mind's eye must allow the surgeon to anticipate structures within the wall and adjacent to it. Thus, even though smooth mucosa or polypoid tissue is all that may be seen, the anatomy of the medial wall should be mentally visualized and anticipated. Sometimes an ostial probe may be placed into the natural ostium from inside the nose. This allows better orientation for location of the surrounding structures. Palpation within the nose may be reflected by movement of the fontanelle area. Direct work may proceed within the sinus using optical forceps. However, only small forceps can be inserted through the trocar. Major work is best accomplished through a wide neo-ostium. If an earlier Caldwell-Luc procedure was performed, firm scar may preclude work or make it difficult.

Frontal sinus trocar technique. If the frontal sinus size can be accurately ascertained from the CT scan, a "6-foot" Caldwell plain film of the sinus is necessary. Otherwise, a template is used to outline the sinus. The supraorbital neurovascular bundle is found at the midpupillary line and the bony notch is palpable. The trochlear nerve is within the field medially.

Opening of the frontal sinus. Although the floor of the sinus is thinnest, the better view is through the face. A small incision is placed in the relaxed skin tension lines and beveled to prevent transection of eyebrow hair shafts. Sharp and blunt dissection then continues to bone. A 4-mm diamond drill is used to create a window into the sinus. Direct rotary pressure motion on the trocar to achieve penetration is not useful. Thereafter, the trocar sleeve is placed and endoscopy begins. Afterwards, a multilayered closure is performed.

Optical forceps in frontal sinus. Usually the endoscope is used to guide the intranasal instrument. Sometimes the optical forceps are used to remove small amount of tissue for biopsy or culture, or to remove small mucosal lesions. Additionally, suction and irrigation can help determine degree of nasofrontal communication.

Trocar endoscopic view of the inner frontal sinus. As the frontal sinus is entered, the 70° endoscope is used to visualize the ostium. Care must be taken not to exert excessive pressure on the posterior table, which may be eroded in polypoid disease. Indeed, initial work from the nasal side is generally sufficient to clear the frontal sinus. In Kerrison punching or in movement of the double-spoon angled forceps, however, a confirmatory view may be useful.

Trocar endoscopic view of the frontal sinus ostium after enlargement. Confirmation that the frontal sinus ostium is patent and guidance of forceps from inferiorly can be useful. A 70° endoscope is used.

Laser Surgery

Endoscopic Rhinologic Laser Surgery. Applications of lasers for sinus surgery are being explored and indications continue to expand. Carbon dioxide, Nd:YAG, potassium titanyl phosphate (KTP/532), and argon are wavelengths that are established for surgical use. Precise tissue incision and hemostasis are two main contributions that lasers can bring to surgery. The logistics of laser technique and patient preparation are the main disadvantages. The laser may be used alone or in combination with standard techniques in sinus surgery. Areas of special usefulness are familiar hemorrhagic telangiectasias, synechiae, and hypertrophic turbinates.

19: Pediatric Considerations

Sinus disease in children is similar to that of adults yet has distinct differences. Specific risk factors seen in children include cystic fibrosis, ciliary motility problems, absence of host immune defenses, and asthma. Thus, a child with a very apparent sinusitis must be watched with suspicion for these pathologies. The converse is also true.

Surgically, there are important differences between children and adults. The smaller size and blossoming shape of the developing sinuses makes for a dynamic mental picture of childhood sinus anatomy. Also, the child's psychology is less tolerant of manipulation.

The use of pediatric endoscopic instruments allows greater surgical agility. The millimeters gained by using smaller, narrower endoscopes and instruments allow better visualization. The smaller instruments also fit the need for smaller neo-ostia. A typical example of this is seen in the use of adult and pediatric back-biting forceps.

The floor of the maxillary sinus is not level with the nasal floor until full development of the permanent dentition with pneumatization around the tooth roots. Penetration of the maxillary sinus along the inferior meatus for trocar visualization or sinus irrigation may not be possible. Thus, a Caldwell view x-ray is used to discern the sinus floor. Obviously, dentition under development is a hazard to Caldwell-Luc type approaches.

Cystic Fibrosis

Cystic fibrosis is a disorder of the exocrine system that produces abnormal secretions in many glands. Recurrent pulmonary and pancreatic problems are common. Early childhood is the most common presenting age group. Diagnosis is made by the pilocarpine-induced sweat chloride test. Staphylococci, but especially *Pseudomonas,* are very common pathogens. The sinuses and nasal cavity often contain polyps in the children, and polyps are increasingly frequent into adulthood. If the nasal/sinus disease is treated, the pulmonary condition may improve dramatically. Endoscopic pansinusectomy in adults is straightforward, but extirpation is less easily accomplished in children. In general, repeated surgery is needed to clear recurrent mucosal polyps even in otherwise well treated and aerated areas. This is a mucous membrane problem. Treatment of the lung condition is primarily by vigorous pulmonary hygiene and antibiotics. Enzyme replacements are used for pancreatic deficiencies and mineral supplements.

Disorders of Cilia

Ciliary motility problems are a spectrum disease. Kartagener's syndrome is but one subtype. Recurrent pulmonary, sinus and ear infections are hallmark. Later, infertility problems are common.

Diagnosis may be made by biopsy of the inferior turbinate mucosa with fixation in glutaraldehyde. Electron-microscopic examination showing a deficient "9+2" microtubule arrangement is pathognomonic. Dysfunction of the cilia can be demonstrated by light microscopy. For these patients, drainage by gravity is important, so the sinuses should be widely opened. The maxillary sinus in adults may receive an inferior as well as a middle meatus antrostomy. In children, however, the floor of the maxillary sinus may be above the nasal floor to a considerable degree. A Caldwell view radiograph can discern this. Treatment of the lung disease is by vigorous pulmonary hygiene and antibiotics.

Immune System Problems

If an immune defense problem is diagnosed, the sinus cavities should be widely opened so that no infected material is sequestrated. Also, the propensity to sequestration by periodic infectious ostial narrowing is thus eliminated. The underlying pathology is treated as necessary.

Asthma

Asthma is a common problem often arising in infancy or childhood. Presumably, inflammatory reactions at the mucous membrane surfaces induce hypersecretion and bronchoconstriction.

Diagnosis is based on findings of prolonged expiratory breathing phases with audible wheezing and abnormal pulmonary function tests. IgE levels are often evaluated.

The nasal passages and sinuses of patients with asthma often show edematous mucosa with polyp formation. Indeed, massive polyps are not uncommon. Often these polyps are responsive to steroid sprays and short oral regimens. No steroid injections into the polyps are given for fear of optic embolization. An allergy evaluation with possible allergy shots is very useful. Surgical polypectomy with wide opening of the sinuses and ostia is performed after a medication trial. Of note is that postoperative nasal steroid sprays are effective in preventing recurrence of polyps. With time, however, repeated polypectomies even in the case of a previously well executed sinusectomy are often necessary, as this is a mucosal disease. Treatment of the pulmonary problem is with vigorous pulmonary hygiene, bronchodilators, and physical therapy.

20: Postoperative Care

To help the newly treated tissue bed heal most expediently and to protect the patient against problems until healing is completed, a number of precautions are taken.

The patient is asked to refrain from blowing the nose for 2 weeks. If a communication exists between the sinuses and the eye or intracranial contents, air may be introduced into these areas. The air may cause anatomic shifts leading to dysfunction. The most severe may be vascular stroke due to arterial kinking. Additional problems may be encountered with pneumocephalus and contamination of brain and meninges by bacteria. If the patient is uncomfortable due to lack of nasal blowing and mucous drainage is severe, then suctioning of the nose in the office usually gives relief. Decongestants are of ancillary usefulness. Along these same lines, the patient is instructed to sneeze or cough with mouth open so that the sudden increased air pressures are vented through the mouth.

In almost all patients, packing is avoided. Even larger sphenoethmoidectomies lead to little problem with bleeding if adequate hemostasis is achieved by vasoconstriction at the time of surgery (see Chapter 16). This situation is probably analogous to the relative absence of bleeding experienced in even massive facial trauma after initial clotting has been achieved. The possible exception may be after endoscopic frontal sinus surgery with enlargement of the nasofrontal ostium. In such cases the localized frontal packing is removed after 3 days. If a general anesthetic is used, postoperative bleeding, and therefore nasal packing, is common. Also, by avoiding packing, the chances of toxic shock and myospherulosis are lessened. If packing is used, it is saturated with a water soluble antibiotic agent. Usually, at the end of the procedure, a large neurosurgical pledget with string is soaked in a vasoconstrictive agent and temporarily placed in each operative ethmoidal cavity. This prevents any bleeding as the patient coughs during initial arousal from the sedation. After an alert state is achieved in the recovery area, the pledgets are removed and a "moustache" drip pad is applied. Repeated gathering of blood-tinged mucus and serum on the pad may necessitate changes each few hours at home for 2 to 3 days.

Oral antibiotics as an extension of the intraoperative intravenous loading dose are continued for 2 weeks. No other medications or ointments are placed into the nose intraoperatively. Pain medications by mouth are useful as are decongestants.

The patient's comfort level is increased if the head of the bed is elevated for several days postoperatively. There is less subjective "pressure."

The patient returns to the office 7 days after surgery. At this time, gentle suctioning removes mucus and crusts. Direct rhinoscopic examination or endoscopy is used. Often the surgical site is still very tender to touch, and large manipulations and cleansings are not well tolerated. At 14 days, the patient again returns. At this time, a thorough suction and forceps cleaning is easily tolerated by adults. Children are reexamined under brief anesthesia 10 days postoperative for a thorough cleaning of the operative sites.

The patient is started on saline nasal self-irrigations using a 3-oz bulb syringe and a solution prepared by mixing 1 tablespoon of salt in 1 liter (quart) of warm tap water. Boiling is required if well water is used. Irrigations are continued for 10 days. The twice-daily irrigations are followed each day by a steroid nasal spray. Follow-up examinations continue with the time between visits lengthening until the tissue bed has healed completely.

Any other problems are addressed as they arise. Usually these are concerned with the patient's need for psychological reinforcement.

21: Complications of Endoscopic Sinusectomy

Toxic Shock Syndrome

Toxic shock is an unusual sequela of sinus surgery but has potentially devastating consequences. The hallmark characteristics are of an acute, febrile, exanthematous illness associated with progressive multisystem failure. The illness is of rapid progression. It begins with malaise, fever, pharyngitis, diarrhea, vomiting, and a scarlet fever-like rash. This progresses to cardiovascular shock, renal failure, and adult respiratory distress syndrome.

The shock is probably multifactorial but is caused primarily by a toxin elaborated by *Staphylococcus aureus.* The toxin that has been isolated in about 63% of cases not associated with menses and is named toxic shock syndrome toxin-1 (TSST1). Approximately 7% of the population carries a TSST1-producing Staphylococcus. About 98% of individuals with TSST1 Staphylococcus have significant antibodies to the toxin. Persons with low antibody titers are thought to be susceptible to toxic shock.

Preoperative antibiotics are unsuccessful in averting TSS. There is correlation with cotton gauze (Nugauze) packs and gelatin sponge (Gelfoam). Synthetic foam (Merocel) may be less provocative. Bacitracin ointment, though effective in vitro against *Staph aureus,* is not prohibitive in vivo on packing. Preoperative preparation with povidone iodine is not preventive.

A patient with characteristic symptoms and signs within 24 to 48 hours after nasal or paranasal sinus surgery should be seriously considered for treatment. Any source of a localized infection should be eradicated. Tampons, abscesses, and other unassociated wounds need to be dealt with by removal and debridement if necessary. Thus, any nasal packing should be removed. Antibiotics that are Staphylococcus effective, such as nafcillin, cephalosporins, or clindamycin, should be given. The disease course is not significantly altered by antibiotics but recurrences are reduced. Corticosteroids are administered early in the disease course. Large volumes of crystalloid and colloid fluids may be necessary. Intubation with positive pressure ventilation may be of additional support. Renal dialysis is uncommonly needed. A team approach to management should be considered.

Myospherulosis

Myospherulosis is recrudescent foreign body reaction associated with implanted petrolatum or mineral oil-based products. The petrolatum is commonly introduced into the body by packing of a surgical site or oil-based injections. The lesion is an inflammatory nodule containing aggregates of red cells in saccular formations. The sequestrated corpuscules lead to development of foreign body granulomas. The spectrum of pathology ranges from soft tissue granulomas to osteolytic bone lesions.

Treatment revolves around surgical debridement of the petrolatum-exposed and reacting areas. The recurrent nature of the nodules makes treatment difficult.

To avoid myospherulosis, exposure of surgical beds, where red cells are prevalent, to petrolatum products is minimized. Thus, packing is saturated with nonpetrolatum, water soluble agents. Water soluble antibiotic creams or solutions containing bacitracin, chloromycetin, gentamicin, neomycin, polymixin B sulfate, and povidone iodine are available.

Hemorrhage

Hemorrhage of minor as well as major proportions during sinus surgery is a problem. Interruption of technique due to visual obliteration of the field results. Constant blood "oozing" is distracting. Landmarks are obscured. In turn, increased operating times result. Increased difficulty of technique may lead to increased morbidity. In turn, minor problems may cascade. Also, potential for death from carotid hemorrhage exists. Thus, control of bleeding is of primary importance during endoscopic sinus surgery.

If bleeding is excessive with frequent interruption of technique, despite local vasoconstrictive efforts, the procedure can be terminated. Reoperation under more controlled circumstances is then elected.

Intraorbital Hemorrhage

Hemorrhage within the orbit can be a very serious result of endoscopic sinus surgery. It can occur in spite of careful technique. Vasoconstrictive local anesthesia will decrease bleeding and help the surgeon visualize surgical landmarks for three-dimensional orientation. This lessens the chance of orbital penetration.

Hemorrhage within the orbit may present very dramatically. Indeed, within seconds to a few minutes manifestations can arise. Conjunctival swelling and subconjunctival bleeding may be evident. The globe may become exophthalmic, and palpation may reveal extreme firmness. The eyelids may splay open and voluntary closure may not be possible. Extraocular movements may become restricted or disappear. Finally, vision may disappear. It has been determined by studies during retinal artery occlusion that anoxia for 40 minutes may be tolerated by the retina. In these situations, actions to help prevent blindness are instituted quickly. A team approach between otolaryngologist and ophthalmologist is of major importance at this point.

Initially, a 4 x 4 gauze sponge is placed over the eye with the lid closed. Firm but gentle pressure is applied. The central retinal artery and vein will collapse if pressures exceed 40 mmHg. Thus, excessive pressure is avoided. Gentle "massage" is used to decrease the intraocular pressure.

If the bleeding is venous, it will usually stop within 1 to 2 minutes. If this is the case, the procedure is terminated and the patient is observed overnight at bedrest. The head of the bed is elevated 30-45°. Vision and pupil checks are performed each hour around the clock. CT scans are generally not helpful because treatment is not changed.

If the bleeding is arterial, initial tamponade trials will usually not halt the progression of symptoms. Continued pressure from within the orbit will progressively push the globe anteriorly. The eyelids begin to splay. The optic nerve itself is capable of stretching by approximately 8 mm. Direct compression by the hematoma on the optic nerve causing ischemia will cause the retina to die. Also, as the optic nerve stretches, its angle relative to the bony optic foramen changes and bony impingement may ensue. In these situations, a lateral canthotomy is performed. To effect a lateral canthotomy, the tenotomy scissors are placed with blade externally and the other on the conjunctiva of the lateral canthus. A straight lateral cut is performed. If an inferior cantholysis is elected, it is accomplished by directing the initial cut of the lateral canthotomy inferiorly. This maneuver detaches the lower lid suspension. Additional decompression can be gained by continuing this cut inferiorly through orbital septum. Another technique is to use a complete lateral cantholysis. The medial canthus is left intact as there are no further gains by a medial cantholysis.

Osmotic agents such as mannitol may be given to shrink the vitreous. Thereby, a collapsed retinal artery may reestablish flow. A retinal examination will help to determine whether the artery is collapsed.

Corticosteroids should be started immediately if any afferent defects are noted (Marcus-Gunn pupil). A Marcus-Gunn pupil is diagnosed by an absence of pupil constriction if light is shone only into the affected eye but bilateral constriction if contralateral illumination is used.

Finally, a bony orbital decompression may be performed. Either a Caldwell-Luc procedure with removal of the orbital floor or ethmoidectomy with removal of the lamina papyracea are the approaches used (see Chapter 10). The periorbitum is incised to release the intraorbital pressure by allowing fat to herniate into the newly created space.

Sphenopalatine Artery Hemorrhage

Sometimes during operative dissection, the area of the sphenopalatine artery is uncovered. Most often, as mucosa is removed from bone, the artery is seen to stretch between the bony ostium and the mucosa. In this instance, a bipolar cautery is used to occlude the vessel. If the artery is violated and bleeding is noted, the endoscope is used to pinpoint its location. A distinct pulsatile stream of blood can often be seen. If the patient is awake, immediate suctioning of blood is necessary to prevent coughing and disruption of the procedure. Thereafter, repair can proceed.

To treat intraoperative bleeding or if the patient initially presents to the physician because of nasal bleeding, the endoscope is used to locate the bleeding source. A Frazier tip suction follows the stream of blood to its source and guides the surgeon to the bleeding point. For a newly presenting patient, the apparent "posterior bleed" may be traced to the anterior ethmoid branches of the septum. Regardless of whether the source is sphenopalatine or the anterior ethmoid septum, the approach to hemostasis is the same: Lidocaine with epinephrine is injected adjacent to the site so that a tamponade usually occurs. Thereafter, a narrow, curved-tip bipolar cautery is used to seal the vessel under endoscopic guidance. Alteratively, a monopolar cautery with a short (3-mm) exposed needle tip may be used after grounding of the patient. Bleeding uncontrolled by this approach will need packing followed by cautery or even artery ligation under more controlled circumstances.

Ethmoid Artery Hemorrhage

The ethmoid artery courses along the skull base from lateroposterior to anteromedial. After removal of the agger nasi cells, the frontal sinus ostium becomes visible. Approximately 2 mm behind the ostium, a bony canal covering the artery is often seen. Sometimes it is less than obvious. This is an area of thin skull base, and the artery may be easily opened.

If the artery is opened, profuse bleeding may occur. A steady stream of blood will drip into the field. An epinephrine-soaked gauze strip is used to pack the area. After several minutes, the pack is removed. If bleeding continues, bipolar cautery to the area is indicated. Thereafter, a piece of gelatin foam sponge is placed to protect against further manipulation. If cautery is not possible, packing may be needed in the area for 47 to 72 hours.

If rebleeding occurs after the pack is removed, the artery should be ligated using an external approach. If the artery retracts into the orbital confines, a rapidly enlarging hematoma may actually endanger vision. In this case, treatment for an intraorbital hemorrhage takes place.

Intraocular Muscle Injury

Entrance into the orbit may lead to muscle injuries. Predominantly, these are medial rectus injuries. If the muscle is completely transected, repair is probably impossible because the medial segment will retract to the muscle cone. Lesser injuries may range from mild temporary dysfunction to permanent muscle imbalance. After healing has taken place and the injury is at a stable point, recession surgery may be able to correct the problem. An ophthalmologist should be consulted if muscle injury occurs.

To help prevent these injuries, the surgeon should avoid probing and manipulating the orbital fat encountered after removal of the lamina papyracea. External ballotement of the globe may reveal intranasal movement if orbital fat has been exposed. Additionally, fat floats on water and this should be noted if it occurs in the specimen container. Also, complaints of ocular pain during an awake procedure should be attended to and the possibility of intraorbital penetration considered.

Cerebral Spinal Fluid Leakage

Discrete violation of the meninges with subsequent cerebrospinal fluid leakage is an infrequent but not necessarily preventable problem. The fovea etmoidalis may be thinned or rendered dehiscent by eroding ethmoidal disease. Indeed, the anterior ethmoid fovea, especially where the anterior ethmoidal artery leaves the ethmoid to enter the olfactory fossa, is intrinsically a place of least resistance in the anterior skull base. Slight manipulation of the skull base may cause a bone fragment to dislodge with a dural leak resulting. Previous external trauma may have caused the cribriform area to crack, splinter, and scar causing a predisposition to CSF leakage. The middle turbinate may be only loosely attached by the conchal lamina. Manipulation of it may cause separation from the skull base, opening small CSF leaks at the olfactory fibers. Specific techniques associated with iatrogenic CSF leakage are complete resection of the middle or superior turbinates or traumatization of the cribriform plate.

It is likely that micro CSF leaks occur, close spontaneously, and remain unrecognized. A leakage that comes to light postoperatively is often located by using a radioactive isotope scan and intranasally placed pledgets. A coronal CT scan of the skull base can then precisely image the area in 1-mm sections. Intrathecal fluorescein with direct endoscopic visualization may be of use intraoperatively during repair.

A CSF leakage may be recognized at the time of surgery. This is advantageous because repair may proceed forthwith. Starting several days after surgery, granulation tissue, crusting and scar formation make repair more difficult.

Surgical Technique

1. The operative field is cleared of purulent and polypoid sinus disease by completing the necessary surgery. Thus, a "clean" tissue bed is established. High dose intravenous antibiotics are given.

2. The mucosa around the leak is gently removed with a small cup-type forceps for 1 to 2 mm.

3. A mucosal free graft is harvested from the inferior or middle turbinates. The graft is large enough to cover the leakage site with several millimeters extra.

4. The graft is placed over the fistula. If tissue glue is available, this graft may be adhesively affixed. The graft is placed mucous membrane side outward.

5. Absorbable gelatin foam sponge is placed over the area and followed by antibiotic-impregnated gauze strip packing. Upon removal of the packing 7 to 10 days postoperatively, the gelatin sponge prevents avulsion of the graft.

6. A lumbar drain is placed in larger leaks for 5 days.