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Surgical management of chronic rhinosinusitis

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The understanding of rhinosinusitis has increased dramatically over the past 2 decades, and sinus disease increasingly is recognized as having a major impact on health-related quality of life [1–3]. Patients frequently are frustrated by their symptoms and seek care from traditional and naturopathic physicians. Patients with recurrent or chronic sinusitis frequently want a cure. When medical therapy has been ineffective, they often turn to surgeons for help. It is important to educate patients that surgery, although effective in some patients, does not always cure the disease. Surgery may help lessen disease frequency or severity. Surgery provides one component of an overall comprehensive plan for management of sinus disease, which frequently requires ongoing medical therapy after surgery. The goal of this article is to provide practicing allergists and immunologists with an overview of some of the surgical thinking and techniques related to sinus disease.

Anatomy of the paranasal sinuses

The anatomy of the paranasal sinuses is complex and varies among humans. The key to understanding sinus disease is the ostiomeatal complex (OMC), which is bounded by the middle turbinate medially, the lamina papyracea laterally, the roof of the ethmoid sinus superiorly, and the opening into the middle meatus and infundibulum inferiorly. This area essentially constitutes the anterior ethmoid sinus and is where the frontal, maxillary, and anterior ethmoid sinuses drain. The attachment of the middle turbinate (basal lamella, also called the grand or ground lamella) separates the anterior from posterior ethmoid cells. [4]. The posterior

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ethmoid air cells and sphenoid air cells drain into the sphenoethmoidal recess [5]. The agger nasi air cell can be appreciated just anterior and superior to the middle turbinate insertion into the lateral nasal wall [6,7]. This cell is usually a pneumatized air cell. The importance of the agger nasi cell is that its posterior boundary is the anterior portion of the frontal recess [8]. Enlargement of the agger nasi cell or disease within it is one of the principle reasons for poor drainage from the frontal sinus in the absence of previous surgery.

The surgical anatomy into the sinuses by way of the endoscopic route can be thought of as a series of doors or lamellae. The first lamellae is the uncinate process, which is a thin sickle-shaped bone arising from the lateral nasal wall that is seen anteriorly as one enters the middle meatus. The second lamella is the ethmoidal bulla, the largest ethmoid air cell. The third lamella is the basal lamella of the middle turbinate; and the fourth is the lamella of the superior turbinate. Surgeons operating in the nose can choose to go through one or more of these lamellae to access various sinuses depending on the extent of disease and the philosophy of the treating surgeon in managing sinus disease.

The hiatus semilunaris is a crescent-shaped cleft or passageway between the posterior margin of the uncinate process and the anterior wall of the ethmoid bulla. It is through this two-dimensional cleft that the middle meatus communicates with the ethmoid infundibulum. This infundibulum is a funnel-shaped structure or passage through which the secretions from the anterior ethmoid cells, the maxillary sinus, and, in many cases, the frontal sinus are transported into the middle meatus. In surgery, an extensively pneumatized agger nasi cell can be mistaken for the opening into the frontal sinus; if the agger nasi cell is manipulated, there is the possibility for scar formation and iatrogenic stenosis or obstruction of the nasofrontal recess [6].

The maxillary sinus (antrum of Highmore) is usually a single chamber, with the orbital roof situated superiorly, the hard palate and alveolus inferiorly, the zygomatic process laterally, and the infratemporal and pterygopalatine fossae posteriorly. The uncinate process, membranous fontanelles, and inferior turbinate form the medial boundary. The natural maxillary sinus ostium usually is located in the most posteroinferior one third of the infundibulum. A common anatomic variation in this region is an infraorbital ethmoidal cell (Haller cell), which can enlarge and encroach on the drainage from the maxillary sinus into the infundibulum [9]. Another anatomic variation is hypoplasia of the maxillary sinus, which can fool clinicians who are doing transillumination into thinking that the sinus is opacified. A hypoplastic maxillary sinus may look like an opacified sinus on plain sinus radiographs, whereas a CT scan usually defines the area of hypoplasia or atelectasis well [10,11].

For surgeons operating in the posterior ethmoid sinuses or sphenoid sinuses, it is important to have an appreciation of the close proximity of the orbit and optic nerve and the anterior skull base, carotid arteries, and adjacent cavernous sinus with its cranial nerves. If the sphenoid sinus is pneumatized well, the optic nerve and carotid artery can indent the sinus. In 20% to 25% of patients, there is a thin or nonexistent bony covering.

Anatomic variations

Anatomic variations frequently are found on sinus CT scans. These anatomic variations may impair mucociliary clearance and sinus ventilation, potentially predisposing patients to sinusitis [12,13]. Several common anatomic variations that have been implicated in OMC obstruction include aerated middle turbinates (concha bullosa) [14,15], Haller cells, paradoxically bent middle turbinates, uncinuate process abnormalities [16], enlarged ethmoidal bullae, and, in some circumstances, septal spurs impinging into the middle meatus. Before implicating these anatomic variations as an etiologic factor in sinusitis, one must remember that these anatomic variations are present in many people without sinus disease [17–19].

Etiologic factors in sinus disease

Three factors are crucial in the normal physiologic functioning of the sinuses: a patent OMC, normal mucociliary transport, and normal quantity and quality of secretions. Disruption of at least one these factors can predispose to inflammation and infection of the sinuses. Endoscopic sinus surgery (ESS) attempts to address the patency issue. The guiding principle behind ESS is to open the OMC to facilitate drainage and ventilation of the sinuses. In diseased sinuses, the hope is that normal mucociliary transport and secretions will ensue, improving or normalizing the sinus environment.

Many forms of traditional of sinus surgery also attempt to create ventilation and drainage; however, some of the drainage openings that are created are in locations different than where mucociliary flow is directed. Following the work of Mes-sinklinger [20], surgeons became aware of the importance of opening the natural ostia. If an opening is created in a location other than the natural ostia, the cilia will continue to beat the mucus blanket toward the natural ostia. If the natural ostia are blocked, the sinus will not necessarily drain. Many traditional sinus operations take the notion that sinus mucosa has become damaged irreversibly from the effects of chronic inflammation and infection. It was common practice to strip out the mucosa from the sinuses in addition to attempting to create a ventilation and drainage pathway. Moriyama showed that bone denuded of mucosa heals much slower, with an associated reduction in ciliary density [21]. Traditional techniques may achieve wider cavities but not necessary resolution of the cycle of reinfection based on the above findings.

Nasal endoscopy

With the development of the Hopkins rod lens system in the early 1950s, endoscopy of the upper airways greatly expanded secondary to superior visualization. This technique was adopted in nasal and sinus examination, and modern-day techniques employ flexible fiberoptic or rigid fiberoptic telescopes [22,23].

Diagnostic nasal endoscopy allows for the characterization of the nasal anatomy with identification of pathologic states that are not identified easily by traditional anterior rhinoscopy. A comprehensive nasal examination proceeds in an orderly fashion using a rigid nasal telescope (2.7 mm or 4 mm; 0° or 30°) or flexible fiberoptic telescopes. A topical vasoconstrictor or topical anesthetic can facilitate the examination. Careful attention is paid to the state of the nasal and middle meatal mucosa, presence or absence of nasal polyps, purulent secretions, or any evidence of a neoplastic process. After sinus surgery, nasal endoscopy is important for monitoring the nose and sinuses.

Imaging in sinus disease

Plain sinus examinations were once the most commonly ordered studies to evaluate the sinonasal cavities; however, CT scanning is preferred by surgeons, given this technique's greater anatomic detail and precision. In general, coronal CT scans are preferred, as they simulate the endoscopic approach surgeons use in approaching the middle meatus and OMC. Care is taken to examine the CT scans preoperatively and intraoperatively for anatomic abnormalities, evidence of a neoplasm, and mucosal inflammatory disease [17]. Great care is taken to examine for anatomy that may predispose to a complication such as the ethmoid roof hanging low, which could be penetrated, resulting in a cerebral spinal fluid leak [24]; dehiscence of the lamina papyracea separating the ethmoid sinus from the eye; and dehiscence of the optic nerve or carotid artery in the sphenoid sinus, which may predispose to life-threatening hemorrhage or loss of vision. MR imaging is used for neoplastic processes because of the technique's superiority in identifying intracranial or orbital extension and its ability to differentiate inflammation and retained mucus from tumor. It is recommended that the surgeon review the imaging before surgery and have the imaging available during surgery for review and clarification of any anatomic issues. When the frontal sinus or sphenoid sinus are going to be operated on, the addition of axial CT imaging is useful. In the frontal sinus, it is helpful to know the distance between the anterior and posterior tables to get an idea of the potential opening that could be created into the frontal sinus. In the sphenoid sinus, axial imaging is helpful to look at the degree of bony covering over the carotid artery and optic nerves. It is important to note if there are any bony partitions in the sphenoid sinus that may be curving to attach to a carotid artery. In this setting, manipulation of the sphenoid intersinus septum potentially could lacerate the artery.

Functional endoscopic sinus surgery

Functional ESS was popularized in Europe by Messinklinger and Stamberger [25,26] and was introduced to North America in 1985 by Kennedy [27,28]. Many other terms are given to this surgery, including minimal ESS, conservative ESS,

and microscopic endoscopic surgery. The OMC has come to be seen by many investigators as the underlying cause of sinusitis and not merely as one point in disease pathogenesis. This finding has led to an emphasis on the importance of surgically correcting abnormalities in the OMC. In many patients, however, OMC abnormalities are one facet of the problem and not necessarily the underlying cause of the disease. Surgery has an important role in the treatment of sinusitis, but it should be considered as an additional possibility to medical therapy in the management of nasal and sinus inflammatory disease. With the exception of acute (eg, orbital or central nervous system) complications, surgery should be considered only after appropriate medical therapy, including environmental control, have been exhausted or have not adequately controlled the patient's symptoms. Surgery should not necessarily be thought of as a cure but as a means to help improve symptom control. Many patients require ongoing medical therapy after surgery, but the goal is to reduce disease severity and the need for frequent medications.

Drainage of the involved sinus may be sufficient in some patients to facilitate disease resolution. In other patients, there may be underlying abnormalities of the bone. This fact has led to the recommendation of more complete removal of the underlying bony partitions in the area where the mucosa is involved with disease. All attempts are made to preserve normal mucosa.

The maxillary sinus

Several theoretic considerations need to be considered when opening into the maxillary sinus. In a rabbit model, exposure of the maxillary sinus to airflow caused slowing or cessation of mucosal clearance. This finding has led some investigators to theorize that the maxillary sinus mucosa ideally should remain

Box 1. Potential indications for endoscopic sinus surgery

- Recurrent acute sinusitis
- Chronic sinusitis
- Nasal polyposis
- Fungal sinusitis
- Mucocele
- Orbital decompression
- Drainage of subperiosteal abscess
- Dacryocystorhinostomy
- Repair of CSF leaks or encephaloceles
- Pituitary surgery
- Resection of sinonasal neoplasms
- Biopsy of sinonasal neoplasms
- Control of epistaxis

protected from airflow [29]. Nitrous oxide is produced in sinus mucosa, may reach bacteriostatic concentrations, and may have a theoretic advantage in fighting infection [30]. If the sinus opening is too large, concentrations of nitrous oxide may not be sufficient to be bacteriostatic. A large portion of the medial wall of the maxillary sinus is taken up by the uncinate process, which, when diseased and not completely resected, could predispose to persistent disease. When disease is minimal, a small or minimal opening of the natural ostia is preferable, but in chronic long-standing disease, a larger opening may be required to completely facilitate removal of diseased mucosa and bone [31]. Many patients have accessory anterior or posterior ostia, which are usually perforations in the membranous fontanelle that covers the bony opening into the medial portion of the maxillary sinus. It is a frequent observation that mucus recirculates between the natural and accessory ostia; if the two areas are not connected at the time of surgery, there could be postoperative recirculation of mucus, which can cause localized symptoms in that area [32].

The frontal sinus

The frontal sinus is one of the most challenging areas for surgeons in terms of the actual procedure and the potential for disease recurrence. In general, if patients are not having significant symptoms in the frontal sinus, surgery in the frontal recess is not recommended. If surgery is required, it has to be done carefully so as not to strip out mucosa circumferentially, which may predispose to osteitis and narrowing or stenosis of the frontal recess. This result can lead to postoperative iatrogenic frontal sinusitis, which can be difficult to manage and usually requires further attempts at surgical opening. The theory behind endoscopic surgery is that minimal opening of the ethmoid sinus should allow better drainage of the frontal sinus into the frontal recess and ethmoid sinus. The decision to operate in this region requires thorough knowledge of the anatomy and the availability of proper instrumentation. A frequent source of frontal sinus disease is medial displacement of the uncinate process from infundibular disease. In these cases, simple but careful removal of the superior portions of the uncinate process may be all that is needed to improve ventilation and drainage of the frontal sinuses. Other patients may require more meticulous removal of diseased agger nasi cells.

The sphenoid sinus

Endoscopic approaches to the sphenoid sinus include direct approaches between the nasal septum and the middle turbinate with resection of the inferior portion of the superior turbinate to gain access to the natural sphenoid ostia. The other endoscopic approach is transethmoidal through the anterior and posterior ethmoid sinuses. If there is only disease in the sphenoid sinus, a direct approach is recommended; if there is disease in the ethmoid sinuses, the transethmoidal approach is recommended. A thorough understanding of the relevant anatomy is

important to avoid inadvertant cerebrospinal fluid (CSF) leak, carotid artery injury, and optic nerve injury [33,34]. Surgery involving the sphenoid sinus would not be considered routine in the surgical management of most sinus disease cases.

Indications for endoscopic sinus surgery

Indications for ESS are outlined in [Box 1](#). The most common indications are recurrent acute sinusitis (more than four episodes of typical acute sinusitis per year), chronic sinusitis, and nasal polyposis [35]. Endoscopic surgery is effective at marsupializing and decompressing mucocoeles, whereas in the past, many patients required extensive external procedures to achieve the same goal. There are evolving indications for the use of endoscopic techniques in the management of sinonasal neoplasms, particularly inverted papillomas [36,37]. These techniques would not be considered functional, as many of the techniques attempt to remove large areas of mucosa and leave bare bone so as to ensure complete tumor removal.

Recurrent acute sinusitis is typified by attacks of unilateral or bilateral sinusitis that resolves with medical therapy but is recurrent throughout the year. If the history of acute sinusitis is vague or unproved, it may be helpful for the surgeon to see the patient during an acute attack to verify that the patient has acute sinusitis. Endoscopic examination of the patient at the time of an episode of acute sinusitis should show edematous middle meatal mucosa and purulent-looking secretions coming from the middle meatus or, in some cases, the sphenoethmoidal recess. Generally, the coronal CT scan shows anatomic variations in the OMC, such as concha bullosa or Haller cells, which are believed to predispose to poor ventilation and drainage. If the patient does not respond to ongoing medical therapies, such as topical nasal-steroid prophylaxis, endoscopic surgery could be considered to try to reduce the number of infections the patient has in a given year. It is reasonable to consider surgery when these obstructing anatomic variations correspond to an area of recurrent sinus symptoms.

Patients with chronic sinusitis generally have ongoing facial pain or pressure, postnasal discharge, nasal obstruction, and possibly some alteration in the sense of smell. Patients with postnasal discharge or drip as the major presenting symptom, in the absence of other major sinus symptoms, generally are not good candidates for ESS. These patients continue to produce the normal 1 L or more of mucus from their nose and sinuses each day, which manifests as an uncomfortable sensation at the back of their throat.

Nasal polyps are a frequent indication for ESS. The extent of disease removal depends on the extent of disease and the philosophy and skill of the surgeon. Antrochoanal polyps are curable in some patients, but for the most part, nasal polyps are difficult to control, particularly in the acetylsalicylic acid (ASA; Samter's) triad. Patients and physicians frequently are frustrated by disease recurrence, and a careful discussion with the patient before surgery is required to try to minimize disappointment. Many patients with polypoid disease do not have

curable cases. Small-volume disease, localized around the middle meatus or olfactory groove, responds well for periods of 3 to 12 months or more, with short bursts of systemic corticosteroids. When the polyps fill almost the entire nasal cavities, resulting in severe nasal obstruction and anosmia, systemic corticosteroids work for brief periods. Generally in this circumstance, a longer period of relief from the nasal obstruction could be afforded with surgery. Corticosteroids taken peri- or postoperatively can be a helpful adjunct in addition to the continued postoperative use of topical nasal steroids to try to slow disease recurrence. The exact role for leukotriene inhibitors in the management of nasal polyp disease remains to be elucidated.

Fungal sinusitis may coexist with nasal polyps and is recognized by a thick tenacious mucus that has a dark yellow or brown appearance. The mucin sometimes looks hyperdense on CT scan or is associated with calcification. If MR images are performed, there are often signal voids in the areas of hyperdensity seen on CT scan. In the noninvasive forms of fungal sinusitis, it is believed to be important to get all of the thick mucoid material out of all of the involved sinuses at the time of surgery to prevent recurrence.

Instrumentation

A variety of instruments are used for ESS. Adequate visualization usually is achieved with a 0°, 4-mm rigid nasal telescope. The telescope can be attached to a television monitor, or the surgeon can look through the scope and visualize the anatomy directly. A beam splitter can be put on the telescope so that the surgeon can look directly through the telescope and the image can be transmitted to a camera to show other members of the operating team what the surgeon is doing. Other scopes offer different angulations, including 30°, 45°, 70°, and 120° angles of view. The workhorse scope is the 0° endoscope, but for work in the frontal recess or viewing the interior of the maxillary or lateral recesses of the sphenoid sinuses, the angled scopes are helpful.

Powered instrumentation or shavers have revolutionized many aspects of sinus surgery, particularly for removal of soft tissues [38,39]. These shavers initially were adapted for orthopedic surgery, where they were used in joint arthroscopic procedures. A number of manufacturers make similar instruments with various nuances. The basics of the instrument include an opening at the tip of the instrument where soft tissues are sucked into the opening and a blade oscillates back and forth to remove small pieces of the soft tissue, which are suctioned up the tubing and removed. As tissue is débrided, new tissue is brought into the opening of the shaver and subsequently removed. Many of these instruments have their own internal irrigation system to prevent material from occluding the internal suction apparatus. There are various degrees of aggressiveness of these blades, a variety of angulations, and even burs that can be used for bone removal. It often is easier to preserve normal mucosa and be precise with these instruments as opposed to many other standard metal instruments used for nasal and sinus surgery. Drilling of bone is not considered a routine part of ESS but

can be required for some frontal sinus work or special procedures, such as optic nerve decompression.

Computer-assisted navigation has been developed and used [40,41]. The basic idea is to have a patient undergo a preoperative axial thin image CT scan, which is loaded into a computer system in the operating room. The computer uses the axial images and reconstructs coronal and sagittal images. The patient's head is registered in the operating room so that a surgeon can place various instruments on the facial skeleton or intranasally and can see the location of the tip of the probe in three dimensions. Electromagnetic and optical tracking systems are available with excellent accuracy to approximately 1 to 2 mm. The technology is not universally available given its high cost. The systems do not allow surgeons to perform surgery that they could not otherwise perform but are helpful in confirming the anatomy, particularly in revision cases in which the anatomy could be distorted. These devices may be helpful in the management of neoplasms and skull-base lesions and in surgery around critical structures such as in the sphenoid sinus. These systems do not provide real-time imaging; if the anatomy changes during the operation (eg, decompression of a mucocoele), the surgeon must be cognizant of this fact so as to avoid inadvertent injury to normal structures that have moved.

Preoperative patient evaluation

Before elective ESS for inflammatory disease, any infection should be minimized, if possible. This step helps to reduce intraoperative bleeding and facilitate thorough dissection. Medical therapy can include culture-directed antibiotics or systemic corticosteroids for severe mucosal hypertrophy or polyposis. Generally, surgeons discuss the risks, benefits, and alternatives of surgery. Many patients can be frightened off by the potential risks of surgery, including injury to the orbit resulting in the potential for double vision, blurry vision, or blindness. Breach of the anterior skull base with a CSF leak, meningitis, and life-threatening hemorrhage from carotid artery injury are possible [33,34]. The risks for these complications are low, particularly with experienced surgeons [42]. Other complications, such as postoperative hemorrhage, infection, and poor wound healing, need to be discussed. Generally, no guarantee can be given that the surgery will be successful, and the patients must weigh the potential chance for improvement versus the low risk for complications [43,44].

ESS can be performed under local anesthesia with sedation or general anesthesia [45,46]. The choice largely depends on the preference of the patient and surgeon. Local anesthesia with sedation avoids the risks associated with general anesthesia; however, many patients find it uncomfortable to have instrumentation inside of their noses no matter how much sedation or local anesthesia is given. Local anesthesia carries the advantage that the patient's vision and response to pain can be monitored. The orbital periosteum and skull base are sensitive to pain, and a patient who is awake should be able to communicate to the surgeon any feeling of significant discomfort. Some patients

under sedation are disinhibited, which may preclude surgery, or they may swallow or aspirate blood, making the surgery difficult. It is important to discuss with the patient who will undergo local anesthesia with sedation that conversion to general anesthesia may be required if problems arise.

An important feature of ESS is to be able to see what the surgeon is doing. If there is too much bleeding, it is difficult to visualize the important anatomy and pathology. For this reason, it is commonplace to use vasoconstrictors, topically and by injection. Common vasoconstrictors include xylometazoline, phenylephrine, adrenalin, and cocaine. With any of these medications, appropriate care is required to not exceed recommended dosages. The use of catecholamines with the cocaine may initiate or potentiate cardiac arrhythmias. Local anesthetics (eg, 1%–2% xylocaine) mixed with various concentrations of adrenalin (eg, 1:100,000–1:200,000 epinephrine) can be injected into the lateral nasal wall or other intranasal structures. Some surgeons find that a sphenopalatine block by way of an intranasal or intraoral route can facilitate surgical dissection.

After vasoconstriction is achieved, the nasal cavities are examined with rigid nasal telescopes. Diseases of the nose, middle meatus, and nasopharynx and septal deformities are noted. Some surgeons prefer to routinely resect a portion of the middle turbinate, but this step is often not necessary in most routine sinus procedures [47,48]. The sickle-shaped uncinate process is resected, followed by identification of the natural maxillary ostia. If there is no significant disease around the ostia, there is no compelling need to enlarge it further unless there is an accessory ostia where the potential for recirculation of mucus exists. The ethmoidal bulla often is opened and removed to the lamina papyracea. If a concha bullosa exists, it can be treated expectantly if it is small or by resection of the lateral half if it is believed to be impairing OMC drainage. If there is a paradoxical bend to the middle turbinate, so that the turbinates scrolls the opposite way to normal, a portion of the turbinate may need to be resected [47].

If there is no significant disease in the posterior ethmoid or sphenoid sinuses, routine surgery in those regions is not required. If there is disease, great care is required in opening through the basal or ground lamella to access the posterior ethmoid air cells. When the opening of the sphenoid sinus is sought, it is important to stay medial and inferior to try to avoid inadvertent injury to the orbital apex or anterior skull base.

If there is no significant frontal disease, routine dissection in the frontal recess or frontal sinus is not required. If there is disease, use of angled telescopes, angled curettes, and specialized instruments for removal of small bony partitions and pieces in the frontal sinus can be useful. In circumstances in which there is osteitis, there are scarring and bony overgrowth in the region, and standard endoscopic mucosal sparing techniques have not worked, drilling of the bone may be required. There are several approaches to opening of the frontal sinus in terms of the extent of bony removal. Approaches can take the form of a simple opening into the frontal sinus to complete removal of the floor of the frontal sinus (endoscopic Lothrop procedure). With increasing removal of bone comes the increasing complexity of surgery and morbidity for the patient after surgery. In

the case of recalcitrant, chronic frontal sinusitis and osteitis, these procedures can be gratifying for the patient and surgeon once the mucosa heals.

Septal surgery is often not necessary during ESS; however, if there is a significant deviated nasal septum, a traditional septoplasty can be performed through an incision near the entrance to the nose. If a septal deflection precludes good access to one side during ESS, an endoscopic septoplasty can be performed in which the offending pieces of cartilage and bone are removed through a small incision anterior to the middle turbinate [49]. Whichever approach is taken, meticulous tissue handling and care usually prevents mucosal injury, which could result in a septal perforation.

Most standard endoscopic sinus procedures take from 30 to 60 minutes to perform, but there is wide variation, depending on the disease extent and operative procedures required. There is no uniform postoperative regimen. Some patients have nonabsorbable nasal packing placed in their noses for a period of hours to days. Absorbable packing materials also can be placed in the middle meatus or nose and may enhance tissue healing. Some surgeons place various stents in the middle meatus during the initial postoperative phase to prevent adhesions.

Use of prophylactic antibiotics and systemic corticosteroids is not universal. In general, patients use saline rinses for several weeks after surgery to remove nasal crusting. Some surgeons prefer to de crust their patients at regular intervals after surgery, whereas others prefer to allow the crusts to fall out on their own. When the crusting has settled, topical steroid treatment may be started. Topical steroids generally are considered for patients with nasal polyposis, allergic rhinitis, or chronic sinusitis. The length of time patients take a topical steroid depends on the status of their nasal and sinus mucosa during follow-up examinations.

The frequency of follow-up visits is dictated by the disease severity and response to surgical and postoperative medical therapy. Many patients, particularly those with nasal polyps, require the use of postoperative topical corticosteroids. Ideally the topical nasal steroids should be started as soon as adequate healing has occurred, typically 2 to 4 weeks post-operatively. It is important to emphasize to patients that surgery is one facet of treatment and is not necessarily a cure for their disease.

Results of endoscopic sinus surgery

A positive clinical outcome of ESS in dealing with inflammatory sinus disease has been well established. Chronic rhinosinusitis has been found to have a significant adverse impact on patient-perceived functional status and quality of life. Winstead has documented a statistically significant improvement in disease-specific symptoms and patient-perceived global health status at 6 and 12 months after ESS [50]. Hoffman has shown specific symptom improvement after ESS to include headaches, nasal drainage, nasal congestion, sinus infection, and breathing difficulties [51]. Sobol et al assessed treatment results in 393 patients undergoing ESS at 6 and 12 months [52]. A positive outcome was achieved in 80.5% of patients at 6 months and in 69.7% of patients at 12 months. Senior has

documented the treatment outcome at longer follow-up periods [43]. Seventy-two patients were assessed; at an average follow-up of 7.8 years, patients reported a 98.4% subjective improvement in their symptoms. Studies also have focused on the impact of asthma control in patients undergoing ESS for chronic sinusitis. Palmer et al used the number of days and total dose of oral prednisone as an objective measure of asthma control [53]. Fourteen of 15 patients decreased their postoperative prednisone requirement from 84 to 63 days. This finding corroborates objectively that at least in the short term, ESS is efficacious in management of patients with chronic sinusitis and asthma. The likelihood of revision surgery is an important issue. In the series by Senior et al, 18% of patients required revision surgery [43]. The incidence of revision surgery in the series by Sobol was 4.1% within 1 year of follow-up [52].

Conventional sinus operations

The foundations of conventional sinus surgery were developed toward the end of the 19th century and were designed to open into the sinuses and curette or remove diseased mucosa from the sinuses intranasally or by way of an external incision. If opening of the natural pathway was not feasible, wide communication into the nose at another site was created to permit gravitational drainage, or the sinus was obliterated to prevent ingrowth of mucosa and possible recurrence of disease.

Conventional maxillary sinus operations include antral lavage or irrigating to clear infected purulent material from the maxillary sinus. An intranasal antrostomy generally is made under the inferior meatus and in essence creates an opening for ventilation. As discussed earlier, it may not allow proper drainage, as the ciliary blanket continues to propel mucus toward the natural maxillary ostia in the middle meatus. The Caldwell-Luc operation was the standard of care for patients with recurrent or chronic maxillary sinusitis before the development of ESS. It still is used for some cases of fungal disease and massive polypsis and for exposure of the sinus in some disease states. It can be performed under local or general anesthesia [54,55]. An incision is made in the upper gingivobuccal sulcus over the canine fossa, and an opening is created through the anterior wall of the sinus. The opening needs to be large enough to enable inspection of the interior of the maxillary sinus and removal of diseased mucosa. An inferior antrostomy generally is made with this procedure.

Conventional frontal sinus procedures include the frontal sinus trephination, which is used for treating acute frontal sinusitis that is unresponsive to medical treatment. An incision is made in the medial canthal region, and an opening is drilled into the anteroinferior aspect of the frontal sinus to drain purulent material. A form of trephination also is performed in ESS, in which a small needle is placed in a similar location to irrigate the sinus and to see where the fluid drains intranasally to facilitate dissection in the frontal recess.

Other frontal sinus external procedures that have been performed include a variety of procedures to remove various portions of the floor or anterior face of

one or both sinuses. A popular frontal sinus procedure is the osteoplastic flap, which can be performed through a bicoronal incision, an incision made through a forehead crease, or an incision made over the eyebrows connected through the glabella. Generally, the bicoronal incision gives better cosmesis. The forehead skin is elevated down to the supraorbital rims, and the anterior table of the frontal sinus is removed. The disease is removed, and a wide communication into the nose can be created to facilitate drainage. The anterior table is replaced. Many surgeons prefer to obliterate the sinus using fat obtained from other sites or other autologous or nonautologous materials. Whether it is better to provide ventilation or to obliterate a frontal sinus is a matter of controversy among surgeons.

Conventional procedures performed on the ethmoid sinus can include transnasal ethmoidectomy with a headlight, possibly with loupe magnification [56]. Access to the ethmoid labyrinths also can be performed through a medial canthal incision, with elevation of the periorbital and entrance into the labyrinth through the lamina papyracea. The sphenoid sinus can be reached by transeptal and transethmoidal (intranasal, transantral, or external) approaches. The preferred approach for any of these steps depends largely on the preference and experience of the surgeon and the coexistence of ethmoid disease.

Complications of sinus surgery

The operative field is in close proximity to the anterior cranial fossa, the orbits, and the carotid arteries [57]. Potential complications associated with sinus surgery are presented in Table 1. Major complications have a low incidence of occurrence. The surgeon pays particular attention to the preoperative CT scan, which is like a road map for the surgery. Particular attention is given to the roof of the ethmoid sinus (fovea ethmoidalis); the integrity of the bone separating the ethmoid sinus from the eye (lamina papyracea); and the position, shape, and size of the frontal and sphenoid sinuses. The integrity of the bone over the carotid arteries and optic nerves is assessed if sphenoid surgery is planned.

Proper visualization during surgery and identification of important anatomic landmarks are keys to avoiding complications. CSF leaks should be repaired when

Table 1
Complications of endoscopic sinus surgery

Minor	Major
Minor hemorrhage	Severe hemorrhage
Periorbital ecchymosis	Orbital hematoma
Orbital emphysema	CSF leak
Ostial stenosis	Intracranial injury and/or bleeding
Synechia	Meningitis and brain abscess
Tooth numbness and pain	Persistent diplopia
Transient diplopia	Blindness
Disturbance of olfaction	Carotid artery injury
Nasolacrimal duct injury	

they are identified to minimize the risk for meningitis [34]. Penetration of the orbital contents can occur while working within the maxillary or ethmoid sinuses. This event can result in long-term diplopia or blindness. Inadvertent injury to the carotid artery in the sphenoid sinus may result in life-threatening hemorrhage and risk for cerebrovascular accident [33,58]. Sinus surgeons need to be able to recognize these complications early and arrange appropriate management.

Summary

The paranasal sinuses are a complex labyrinth of cells that drain into the nose. One of the important features of sinus health is patency of the sinus openings to allow ventilation and drainage. Equally important is the status of the mucosa and cilia. Surgery in many patients can address the patency issue but not necessarily the mucosa or the cilia. Modern-day sinus surgery attempts to open and ventilate the sinuses with as little collateral damage to adjacent mucosa as possible. The mucosa of many chronically inflamed sinuses vastly improves once this step is achieved. In the authors' experience, the cases of 80% of patients with recurrent acute sinusitis or chronic sinusitis can be improved, although not necessarily cured, with surgery. Cases of nasal polyposis can be improved for a period of time (months to years), but most recur, particularly those that involve the ASA triad. The risks associated with surgery are small. Patients need to weigh the potential improvement in their quality of life versus having to go undergo surgery and the small risk for complications.

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