Functional Endonasal Sinus Surgery in the Pediatric Age Group

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Sinusitis is commonly seen in pediatrics. It is a dynamic, multifactorial process whose symptoms are variable. Upper respiratory tract infections and allergy are the major predisposing causes of sinusitis. Most patients respond to medical treatment. Surgery is generally indicated when optimal conservative management fails.

Functional endonasal sinus surgery (FESS) using endoscopes can form the mainstay of surgical therapy for pediatric patients with chronic/recurrent sinusitis. It is a surgical approach that can potentially restore the physiologic function of the paranasal sinuses. Although it was only introduced 5 years ago by Kennedy,[1] it is becoming a popular surgical treatment for sinus disease in the United States. Most past reports have addressed its use in the adult population.

In children, we believe that FESS may be a curative and safe procedure. Gross et al.[2] were the first to report on its use in the pediatric age group. They reported their experience with a series of 57 patients.

The diagnosis of sinusitis in children may be difficult. The child is frequently unable to communicate many of the characteristic symptoms of sinusitis. Additionally, radiographic findings may be confusing. Ostensibly normal children may have abnormal findings on plain radiographs.[3]

With the introduction of a wide variety of chemotherapeutic agents and new technologies, our therapeutic choices have become very broad. Accurate diagnosis and appropriate decisions can be made when a thorough understanding of the pathophysiologic mechanism of the disease entity is known.

Development and Anatomy of the Paranasal Sinuses

The paranasal sinuses are among the most poorly described anatomic sites in the human body.[4] This is even more evident in children where the sinuses are small and changes in location and size are almost continuous. The sinuses are also in close proximity to critical structures. Therefore, every surgeon should have an intimate understanding of sinus development and anatomy before attempting any surgical intervention of the sinuses.

The sinuses may be understood by the study of their embryology. Each of the four pairs of sinuses is named after the cranial bones in which they are located. All sinuses contain air and are covered by ciliated pseudostratified columnar epithelium, interspersed with goblet-type mucous cells. The size of the sinuses depends on the age of the individuals.[5] Asymmetry of the sinuses may occur in the same individuals.[5]

The Ethmoid Sinuses

The ethmoids have the greatest variation among the paranasal sinuses.[4] The anterior cells first appear in the third fetal month as pits of the frontal recess.[4, 6] The uncinate process and bulla ethmoidalis can be considered as accessory folds.[4, 6, 7] At birth the ethmoids are fluid filled and are difficult to recognize on routine radiography until approximately 6 months of age. By the age of 12 years, the ethmoids are nearly adult size.[4]

The most constant part of the ethmoid sinus is the lateral wall or the lamina papyracea.[4] This is a paper-thin bone that forms the medial wall of the orbit. The ethmoid roof is formed by the fovea ethmoidalis and extends 2 to 3 mm above the medial cribriform plate.[4] The ethmoid cells are generally divided into the smaller but more numerous anterior cells and the larger posterior cells. The anterior cells can be further subdivided into frontal recess cells, infundibular cells, agger nasi cells, bullar cells, and conchal cells.[8]

The anterior and posterior ethmoids are separated by the grand or basal lamella.[4, 9] Other lamellae or septae help to compartmentalize the ethmoids and may offer a barrier to the spread of infection.[4]

The Maxillary Sinuses

The uncibullous groove[4, 7] gives rise to the maxillary sinus in the third fetal month. At birth, the sinus is filled with fluid, making interpretation of plain film radiography difficult.[10, 11] Between birth and 3 years of age, and between 7 and 12 years, the sinus undergoes rapid growth.[4, 10, 12] Thereafter, modest enlargement occurs. Growth is completed by adulthood.[13] The sinus ostium is located in the superior aspect of the medial wall of the sinus. This then drains into the hiatus semilunaris.[4] Variations in ostial location occur; however, most authors agree that the ostium is usually found posterior to the midpoint of the bulla ethmoidalis.[4, 10, 14, 15] Accessory ostia may be found in 15% to 40% of cases.[4, 12, 14, 15]

The Frontal Sinuses

Several origins of the frontal sinuses have been proposed. Kasper, in his study of 100 adult specimens, found that pits or furrows in the frontal recess that were rudimentary anterior ethmoid cells are the most common origin.[4, 6] Less commonly the frontal sinus is derived from direct extension of the frontal recess.[4, 6] At birth, the sinus is indistinguishable from the anterior ethmoid cells.[4] Usually after the fourth year of life, the frontal sinus begins to vertically invade the frontal bone. It can usually be demonstrated radiographically after 6 years of age. Growth is generally completed before the age of 20 years.[4, 13]

The Sphenoid Sinuses

The sphenoid sinus is primarily an evagination of the sphenoethmoid recess with essentially no growth until the age of 3 years.[4] By the age of 7 years, it extends posteriorly towards the sella turcica. Variations in the size are accounted for by possible arrests in development.[4] The sinus is in close proximity to crucial structures such as the internal carotid artery, optic nerve, pituitary gland, and vidian nerve, among others.[13, 16, 17] The close relationship to critical structures makes surgery in the sphenoids potentially hazardous. This sinus usually drains by a single ostium into the sphenoethmoid recess.[4] The ostium is located 10 to 15 mm from the floor of the sinus; hence, drainage depends on mucociliary flow.[4, 16]

Pathophysiology of Sinusitis

The paranasal sinuses were first described 1,800 years ago[5]; however, their exact function is not well understood. Many theories have been proposed, but none of them have met with wide acceptance. Among these theories are that the sinuses humidify and warm inspired air, impart resonance to the voice, and act as a shock absorber during head trauma, among others.[5] No matter what the functional significance of the sinuses are, their physiologic function can be maintained by adequate flow of their secretions. This is achieved by patent ostia and sufficient mucociliary function. Any incident interfering with one or both functions may lead to sinusitis.

Sinusitis is an inflammatory process of the mucosal lining of the sinuses. This process can result in thickening and engorgement of the subepithelium of the sinonasal mucosa with capillary dilation and acute inflammatory exudate. The resulting edema will lead to ostial obstruction, pooling of sinus secretions, and secondary bacterial infection. On the other hand, ostial obstruction or the pooling of secretions might be the primary event leading to sinusitis. The causes are multiple and summarized in Table 1.

The single most important pathologic factor in sinus disease is ostiomeatal complex obstruction. The ostiomeatal complex is the region of the middle meatus where the pathway of mucociliary flow converges from the frontal, maxillary, and ethmoid sinuses. It consists of the infundibulum, hiatus semilunaris, frontal recess, uncinate process, anterior ethmoid bulla (bulla ethmoidalis), and the anterior wall of the middle turbinate (Fig 1). Multiple causes may lead to ostiomeatal complex obstruction. Any cause

TABLE 1.
Etiologic Factors in Pediatric Sinusitis

Inflammatory
Upper respiratory tract infection
Allergy
Mechanical
Nasal/septal deformity
Ostiomeatal complex obstruction
Turbinate hypertrophy
Polyps
Tumors
Adenoid hypertrophy
Foreign bodies
Cleft palate
Choanal atresia/posterior stenosis
Systemic
Cystic fibrosis
Immotile cilia syndrome/Kartagener's syndrome
Immunodeficiency
Cyanotic congenital heart disease
Miscellaneous
Diving, swimming

shown in Table 1 may be a causative factor in ostiomeatal complex obstruction (Fig 2).

Viral upper respiratory tract infections and allergic inflammatory diseases are the most common causes of acute sinusitis in the pediatric age group. However, patent sinus ostia were estimated to be found in 20% of children with acute rhinitis.[18] Allergy also appears to play a significant role in sinusitis. Almost 50% of our 210 pediatric FESS patients had positive testing for allergy.

The mucociliary transport system forms a defense mechanism. This is achieved through the function of ciliary beating, mucous blanket, lysozymes, secretory IgA, and many other surface active enzymes. Conditions such as cystic fibrosis or immotile cilia syndrome may compromise mucociliary function leading to sinusitis. Even a common cold may disturb the mucociliary transport system.

A critical factor that can produce chronic or recurrent sinusitis is mechanical obstruction of the ostia. In contrast to an inflammatory process, which is usually reversible medically, mechanical obstruction is relieved only by surgically removing the obstructing object.

Ostiomeatal complex (OMC) obstruction and ethmoid disease are the

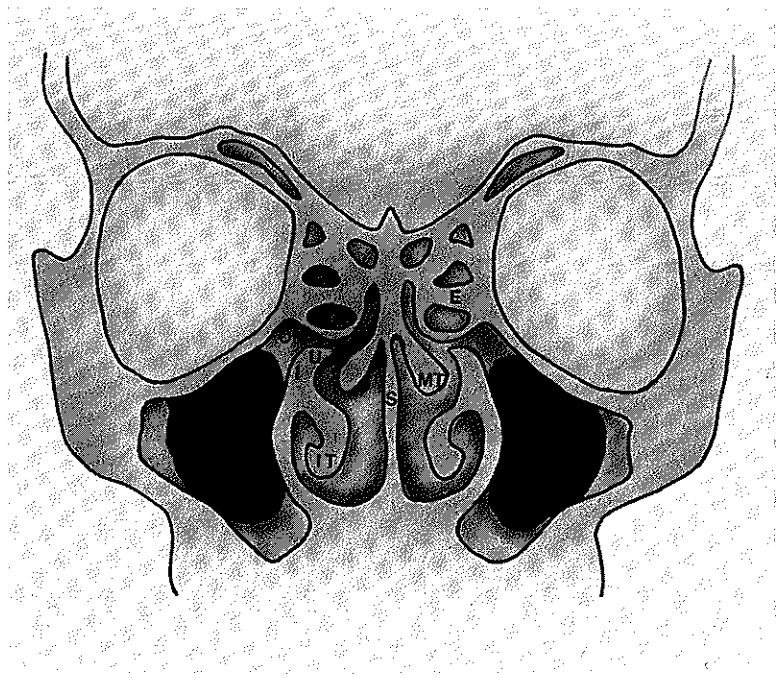

FIG 1.
Normal ostiomeatal complex *(OM)* anatomy: bulla ethmoidalis *(BE)*, maxillary sinus infundibulum *(I)*, uncinate process *(U)*, hiatus semilunaris *(curved arrow)*, inferior turbinate *(IT)*, nasal septum *(S)*, middle turbinate *(MT)*, ethmoids *(E)*, maxillary sinus *(M)*.

key factors in sinusitis. As early as the 19th century, Caldwell stressed the functional relationship between the ostia of the anterior ethmoid, frontal, and maxillary sinuses.[19, 20] He also recognized that maxillary sinusitis may be secondary to other diseases in the region. Schaeffer, in 1916,[21] also agreed with this theory. This was even better illustrated by Proctor, who in 1966[22] stated that the ethmoid sinuses are usually the major factor to any problem involving the sinuses. Additionally, he stated that infection usually begins in the ethmoids and persistent infection is usually the reason for failure of therapy. Better diagnostic techniques using high-resolution coronal computed tomography (CT) and direct visualization with fiberoptic telescopes are the primary reasons why the OMC has been "rediscovered" recently.

Treatment of Sinusitis

The objectives of treatment in sinusitis are rapid sterilization of sinus secretions and reestablishment of the normal physiology of the sinuses. These objectives can be achieved by medical and/or surgical methods.

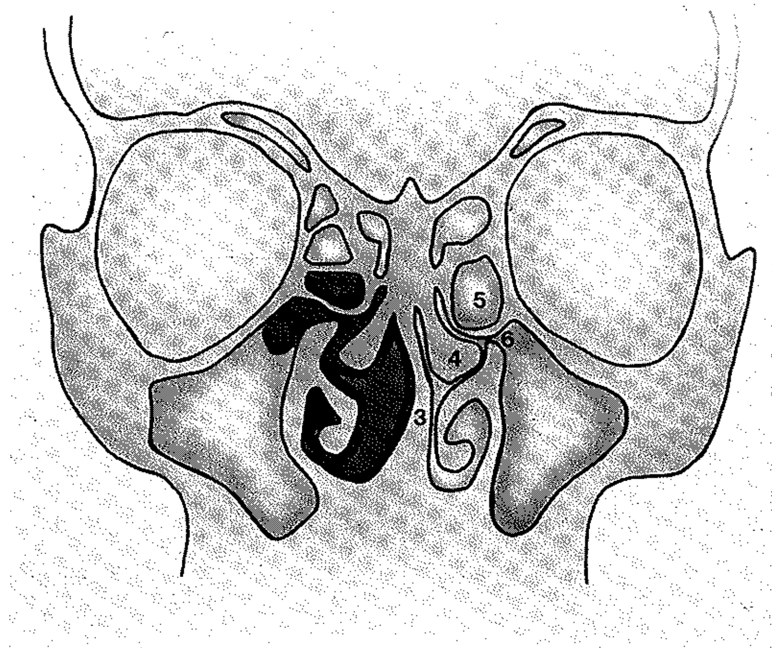

FIG 2.
Ostiomeatal complex obstruction and secondary sinusitis: inflammatory (obstructive) changes *(1)*, polyps (maxillary and ethmoids) *(2)*, septal deviation *(3)*, paradoxical M. turbinate and concha bullosa *(4)*, large bulla ethmoidalis *(5)*, and ostiomeatal complex stenosis *(6)*.

The initial approach should always be maximal medical treatment. Many reports have shown that more than 80% of children with acute sinusitis are cured with adequate medical therapy.[23] The cornerstone of any medical therapy is antibiotics. These should be effective against the major offending organisms. These are *Streptococcus pneumoniae*, nontypable *Hemophilus influenzae*, and *Moraxella (Branhamella) catarrhalis*.[24] In contrast, anaerobes are common in chronic sinusitis and should be taken into consideration when this is being treated. Brook,[25] in a study of 40 children with chronic sinusitis, recovered anaerobes in 100% of cultures and mixed organisms in 38%.

The medical regimens followed are summarized in Table 2. Antihistamines, decongestants, steroids, systemic liquefying agents, and humidification may be used in addition to antibiotics. These agents may help in decreasing edema and improving mucociliary function. However, antihistamines may dry the secretions and make drainage more difficult. Their role has not been clarified and their avoidance, if possible, is initially advised.

Tonsillectomy, adenoidectomy, limited septoplasty, partial turbinecto-

TABLE 2.
Medical Treatment Protocol for Sinusitis in the Pediatric Age Group

Medications	Initial Regimen	Duration	Secondary Regimen	Duration
Antibiotics	Ampicillin, amoxicillin erythromycin, Trimth/sulf.*	14 days	Amoxicillin-clavulanate	21–30 days
			Cefaclor	
			Cefixime	
Decongestants	Pediatric nasal spray/drops	3–5 days	Pediatric nasal spray/drops	3–5 days
			Systemic	21–30 days
Antihistamines	–	–	Occasionally (late in treatment)	7–14 days
Liquefying agents	+	14 days	+	21–30 days
Steroids local (spray)	–	–	+	21 days
Steroids Systemic	–	–	–	—
Humidification	+	7–14 days	+	7–14 days

*Alternative treatment in case of penicillin allergy.

mies, antral lavage, and antral-nasal windows have been used in the past as appropriate surgical modalities for the treatment of children who fail traditional medical therapy. All of these procedures have a place, but the appropriate indications and the effectiveness of each are not well established.

Functional Endonasal Sinus Surgery

FESS is surgery of the ostiomeatal complex. Ostiomeatal complex obstruction is considered to be the major etiologic factor in chronic sinusitis. The goal of FESS is to reestablish conditions that enhance the restoration of normal mucociliary clearance of the sinuses. Disease can be thoroughly removed under direct vision and normal structures are preserved with minimal trauma. Children with persistent sinusitis, despite "maximal conservative therapy," are the usual candidates for FESS.

Coronal CT of the sinuses is a strict prerequisite before FESS is undertaken. In contrast to adults, FESS in children is more challenging. As was alluded to previously, the sinuses are developing, small, and many times asymmetrical. The orbit and the anterior fossa are in close proximity. These can be sites of serious complications in FESS.

Today, coronal CT of the sinuses is the most sensitive diagnostic modality by which accurate diagnosis of ostiomeatal disease and chronic sinusitis can be made. Coronal CT of the paranasal sinuses demonstrates disease not frequently seen on regular sinus x-ray films (Fig 3). It helps in evaluating inaccessible structures and can display anatomic variations, hence aiding in therapeutic planning.

In contrast to CT, plain radiographic abnormalities may also be found in healthy children.[26, 27] In a study of 70 children, Lusk et al.[23] found that plain films both overestimate and underestimate the amount of sinus disease when compared with CT findings (Fig 4).

However, CT is not a perfect diagnostic tool. In our review of 210 patients who underwent FESS, almost 20% had intraoperative findings that were far more extensive than what the CT illustrated. Also, 7% of patients with normal CTs preoperatively were found to have significant disease at the time of surgery.

Children with persistent sinusitis should be thoroughly investigated for systemic disorders. Among these are cystic fibrosis, immotile cilia syndrome, and immunodeficiency. Moreover, allergy evaluations by a pediatric otolaryngic allergist or a pediatric allergist should be performed. If allergies are found, allergy treatment should be initiated and continued following surgery. Almost 50% of 210 patients we reviewed[28] had allergy.

Surgical Technique

The technique of FESS in children is different from adults in many aspects. The preoperative assessment, type of anesthesia, surgical procedure, and postoperative follow-up are not the same.

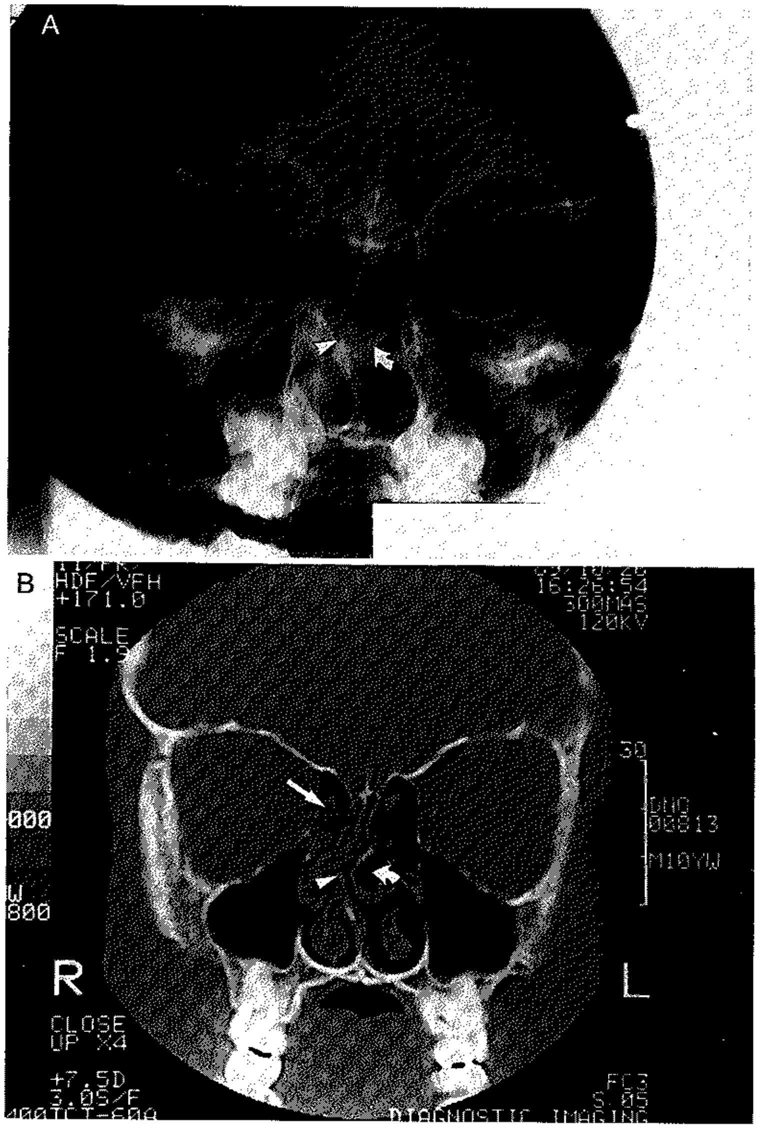

FIG 3.
A, plain x-ray film of the sinuses (Caldwell view) showing right septal deviation *(arrowhead)* and a left concha bullosa *(curved arrow)*, but no sinus disease is apparent. **B,** coronal CT of the sinuses of the same patient in A showing right ethmoid mucosal thickening *(arrow)*, right septal deviation *(arrowhead)*, and left concha bullosa *(curved arrow)*.

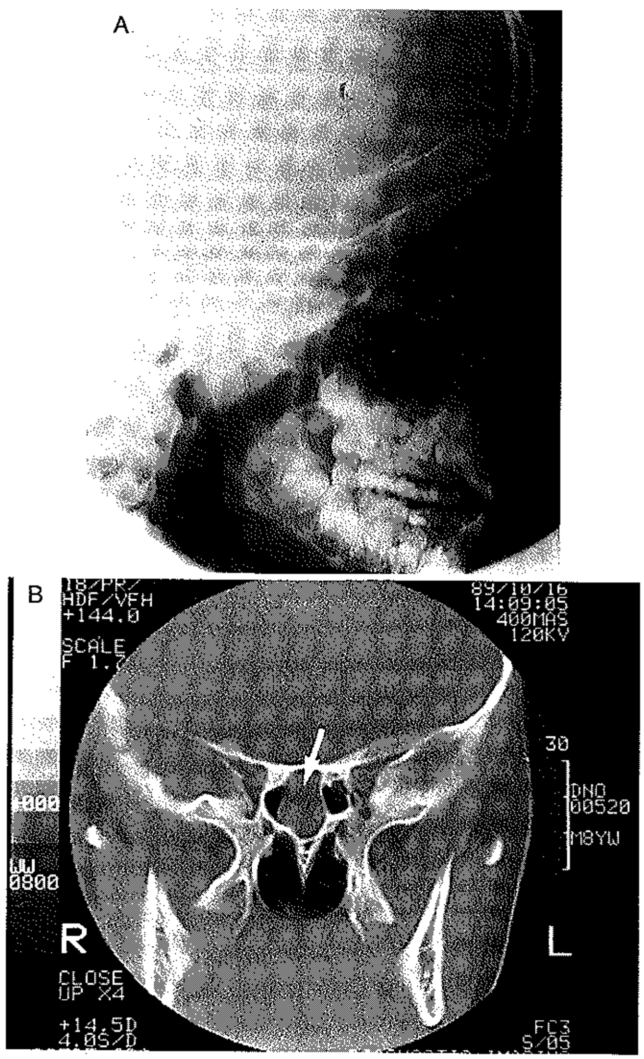

FIG 4.
A, plain x-ray film of the sinuses (lateral view) showing no apparent sphenoid disease. **B,** coronal CT of the sinuses of the same patient in A showing a large right sphenoid mucous retention cyst *(arrow).*

Depending on their age, children in general may not tolerate preoperative and/or postoperative office nasal endoscopy. In contrast to adults, the surgery and the postoperative nasal endoscopy are commonly performed under general anesthesia. Preoperative assessment by nasal endoscopy is not routinely performed.

We reemphasize that the anatomic structures are smaller, the depth of penetration is less, and the relationships to the surrounding structures are altered. All of these factors should be respected when performing FESS in children.

Preoperative Preparations

In children undergoing FESS, the most reliable preoperative assessment is obtained from a coronal CT of the sinuses. Additionally, office nasal endoscopy is very challenging in the pediatric age group. Therefore, nasal endoscopic evaluation cannot be generally performed preoperatively. The first adequate nasal exam may be the one performed intraoperatively.

The technical elegance and the therapeutic outcome of FESS relies to a great extent on the degree of vasoconstriction achieved intraoperatively. Vasoconstriction begins preoperatively. The patient's nose is sprayed with a topical decongestant on call to the operating room. Phenylephrine hydrochloride (Neo-Synephrine) or oxymetazoline hydrochloride (Afrin) may be used with excellent results.

After administration of general anesthesia, the decongestant protocol is continued. The surgical site is injected with 1% or 2% lidocaine solution with 1/100,000 epinephrine using a dental carpule with 27-gauge, 1.5-inch needle. Lidocaine with 1/50,000 epinephrine produces excellent hemostasis; however, it should be used with caution. Additionally, the selection of the anesthetic gases is crucial when injecting epinephrine. Therefore, a good working relationship with a pediatric anesthesiologist is essential.

The nose is then packed with neurosurgical cottonoids soaked in 4% cocaine solution. Afrin or Neo-Synephrine could also be used; however, based on our experience, cocaine provides the best vasoconstrictive effect. The packs should remain in place for a minimal period of 10 minutes. This should be adhered to religiously to obtain optimal visualization and hemostasis.

Procedure

The surgical technique begins by nasally examining the nose. Nasal endoscopy is used to assess the septum, the size of the middle turbinate, the posterior nasal airway, as well as the adenoids if they are present. The CT is always present in the operating room and should be referred to frequently during the procedure.

We use the 4-mm (Storz-Hopkins) nasal endoscopes. The smaller (2.7-mm) telescope is rarely utilized. The smaller telescopes do not provide the depth of field and the degree of vision as seen by the larger (4-mm) telescopes. We have found no difficulty in using the 4-mm telescopes, even on our youngest patient (14 months).

It is important to minimize trauma to the nose. One must utilize the minimum number of instruments to perform the surgery. This will decrease the trauma to the nasal cavity. Therefore, a preconceived surgical plan will aid in decreasing the number of manipulations and trauma.

We begin our surgery by performing an anterior infundibulotomy using a sickle knife and zero-degree, 4-mm endoscope. The infundibulum and the anterior ethmoid air cells are generally exonerated. The posterior ethmoid air cells are opened and any disease present is removed. The sphenoid sinus is generally not opened, except if there is evidence of disease on the CT. Switching to a 30-degree, 4-mm endoscope, and a right-angled suction tip, the frontal recess is then inspected and polypoid disease is removed if present. Next the natural ostium of the maxillary sinus is identified and enlarged three to five times the normal anatomic size using the same telescope gruenwald and backbitting instruments. After widening the natural maxillary sinus ostium, the maxillary sinus is lavaged using saline solution. The 70-degree endoscope may be used to visualize the frontal recess or the maxillary sinus. During the procedure care should be taken to minimize trauma to the medial surface of the middle turbinate, so as to prevent the formation of adhesions or synichiae.

Occasionally a deviated septum, a large middle turbinate, or a concha bullosa may hinder our surgery. In such cases, a limited septoplasty or a partial middle turbinectomy may be performed. This gives us better exposure and facilitates aeration and drainage, hence improving our outcome.

At the end of the procedure, 40 mg of methylprednisolone acetate (Depo-Medrol) is injected in the surgical site and the inferior turbinate. Additionally, antibiotic-steroid ointment is used to fill the surgical site. No packing is generally required. The patient is commonly discharged the same day of surgery.

Follow-Up

Postoperatively all patients are maintained on oral broad-spectrum antibiotics, saline nasal mist, steroid nasal spray, and a nasal decongestant spray. These medications are given for a period of 6 weeks. However, 2 to 3 weeks after the initial surgery, nasal endoscopy is performed under general anesthesia. This is done using the same technique as previously described.

Nasal endoscopy allows for the removal of synichiae, granulation tissues, and clots or crusts that may have formed. Only on rare occasions has a patient required a third endoscopic procedure.

Minimal symptomatology may return in the early postoperative period, probably due to edema. Medical and allergic treatment should be continued, especially during the first 6 weeks after surgery. Thereafter, medical treatment may be tapered and discontinued. However, allergy treatment should continue for the standard length of time to control inhalant allergens.

Study Results

We evaluated a series of 210 patients who underwent surgery between January 1986 and June 1989. The age range was 14 months to 16 years. Approximately 50% had been treated for allergies and 22% were asthmatic. Forty-four percent of patients had previous tonsillectomies and adenoidectomies, 48% had previous pressure-equalizing tube insertion, and 30% had previous sinus surgery. More than 80% of these patients improved. The most common findings on follow-up endoscopy were adhesions and granulation formation. Serious complications, such as blindness, cerebrospinal fluid rhinorrhea, meningitis, or extraoccular muscle injury were not experienced. Sixty-six percent of children who had previous sinus surgery improved after FESS. More than 80% of patients who had asthma claimed their asthmatic problem markedly improved. Almost 8% of patients had a revision FESS, 80% of whom improved after revision.

Conclusion

FESS is proving to be a safe and cost-effective method for the treatment of chronic/recurrent sinusitis in the pediatric age group. It attempts to surgically correct anatomic obstructions that prohibit or impede normal mucociliary clearance of the paranasal sinuses. This is achieved by opening the narrow ostiomeatal complex, removing ethmoid disease, and opening, when indicated, the natural ostia of the frontal, maxillary, and sphenoid sinuses. Serious complications are rare, as demonstrated by our series. The disadvantages include specialized training and instrumentation, requirement of a CT scan, multiple postoperative visits, and postoperative nasal endoscopy under general anesthesia.

Success of the procedure is helped with maximal intraoperative vasconstriction. This allows excellent visualization and meticulous hemostasis. Second endoscopy is also a must for achievement of good results. However, we stress that FESS should only be performed by surgeons who are well trained and experienced in this field. We reemphasize that this operation should be performed only after maximal conservative treatment has failed to cure these patients.

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