Sinusitis in Children: Current Management

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Introduction

Chronic sinusitis and recurrent acute sinusitis are relatively common clinical disorders in children.[1] Chronic sinusitis describes signs and symptoms of sinusitis that persist longer than 3 months despite optimal medical therapy. In recurrent acute sinusitis, sufficient change has occurred in the anatomic structure of the infundibulum or in the efficacy of the mucociliary system to predispose the patient to recurrent bouts of sinusitis. In addition to the immediate discomfort of a bout of sinusitis, the disease may exacerbate other conditions, such as asthma and otitis media, or lead to suppurative complications, such as orbital abscess or cavernous sinus thrombosis.[2]

During the last decade, opinions have changed about the pathogenesis and treatment of chronic sinusitis. It had long been accepted that chronic sinusitis originated in the maxillary sinus and that removal of diseased mucosa by means of a Caldwell-Luc procedure or aeration of the sinus by antrostomy would reinstate the normal sinonasal condition. These concepts and practices were challenged by Messerklinger,[3,4] who made it clear that the origin of sinusitis is the ostiomeatal complex. This region, which includes the uncinate process, the bulla ethmoidalis, the hiatus semilunaris, and the infundibulum, forms the dominant drainage system of the anterior ethmoid, frontal, and maxillary sinuses.

The development of the rod-lens telescope and other effective instrumentation has enabled otolaryngologists to address disease in the ostiomeatal complex endoscopically. In 1989, Gross and Lazar[5] described the successful use of functional endonasal sinus surgery (FESS) in treating children. Since then, its use and efficacy have been reported by many physicians, and the indications for the procedures have greatly expanded. In addition to treating chronic sinusitis, FESS is now used for the treatment of orbital complications such as subperiosteal abscesses,[6] for dacryocystorhinostomy creation,[7] for the repair of limited cranial defects,[8] and for the removal of benign lesions.

This review delineates the current ideas about the development of the sinuses, the pathophysiology of sinusitis, and the treatment of chronic rhinosinusitis.

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Developmental Anatomy

During development, the nasal cavities become surrounded by a condensation of mesenchyme, which chondrifies to form the nasal capsule. Paired cavities called the paranasal sinuses develop as outpouchings from the lateral walls of the nasal cavity. The cavities are lined with mucous membranes that are continuous with the lining of the nasal cavity. The processes of the lateral wall give rise to the ethmoturbinals, which later develop into the turbinates and the ethmoid sinuses. The maxillary sinuses develop as outpouchings of the lateral wall and, with the ethmoid cells, are present at birth.[9]

Wolf and co-workers[10] examined 102 pediatric specimens to determine the growth of the paranasal sinuses from birth to 12 years of age. They found that the uncinate process, ethmoid bulla, and hiatus semilunaris are present at birth but that the bulk of the middle turbinate excludes the middle meatus from the functional nasal airway (Figure 1).

In children between the ages of 1 and 4 years, the ethmoid and maxillary sinuses enlarge, and the middle meatus becomes integrated into the nasal airway. Obstruction of the ostiomeatal unit, with resultant chronic sinusitis, may need to be addressed in these young patients. The frontal and sphenoid sinuses also begin to form, and it is at this point that these structures may begin to contribute to the symptoms of chronic sinusitis.

From 4 to 8 years of age, the maxillary sinus expands, with descent of the floor to the midway point of the inferior meatus. With continued expansion of the frontal and sphenoid sinuses, disease is more likely to develop in this area. Final maturation of the ethmoid and maxillary sinuses occurs during the pre-teen years. The limits of the maxillary sinus become the molar teeth laterally, the floor of the nose inferiorly, and the nasolacrimal duct anteriorly.

Pathophysiology

Effective sinus function relies on mucociliary flow through intact anatomic channels from the sinuses into the nose. The infundibulum and middle meatus are the key anatomic areas into which the frontal, maxillary, and anterior ethmoid sinuses drain.[11] Interference with any aspect of this system may lead to infection, swelling, and chronic sinusitis.

The most common predisposing factors for chronic or recurrent acute sinusitis are viral upper respiratory infections and allergies.[12] Immunodeficiencies, most commonly IgA and IgG deficiencies, can increase the incidence of infection with encapsulated organisms. The IgA component of the immune system is immature at birth and develops over several years.[13] Acquired immunodeficiencies, such as those of patients on immunosuppressive medication, on chemotherapy for treating malignancies,[14] or with acquired immunodeficiency syndrome (AIDS), also predispose the patient to the development of sinusitis. Long- or short-term defects of ciliary transport, such as immotile cilia syndrome and viral infection, respectively, lead to stasis within the sinus cavity and a microenvironment conducive to the development of acute and chronic sinusitis. In mucoviscidosis (i.e., cystic fibrosis), abnormalities in the secretions prevent proper movement of the mucous out of the sinuses. Chemical irritants, such as tobacco smoke, may also play a role in the pathogenesis of sinusitis.

Anatomic variations can lead to blockage of the ostiomeatal complex. Among 69 patients with chronic sinusitis, April[14] found a 19% incidence of concha bullosa, an 18% incidence of Haller's cells, and a 13% incidence of septal deformity. We have witnessed a higher incidence of septal deformity than concha bullosa or Haller's cells. These deformities may disrupt the normal laminar flow of air and cause anatomic obstruction of the ostiomeatal complex.

The role of the tonsils and adenoids in the pathogenesis of chronic sinusitis is not well understood, but it is thought that they may act as bacterial reservoirs. Additionally, partial obstruction of normal nasal airflow may lead to changes in the microenvironment of the sinuses and foster bacterial growth.

Although the cause of sinusitis is probably multifactorial, the lack of proper movement of the mucous blanket can lead to infection and edema. As the natural ostia of the sinuses become narrowed by inspissated secretions or edematous mucosa, bacterial infections develop, worsening the edema and producing the signs and symptoms of acute and chronic sinusitis. Over time, these changes become irreversible, and a pattern of chronic sinusitis predominates.

Several studies have addressed the bacteriology of chronic sinusitis. Studies culturing the ethmoid contents or maxillary sinus lavage have been more effective in determining pathogens than those employing nasal culture. Wald and colleagues[15] studied the microbiology of the antral lavage in patients with acute and subacute sinusitis. Streptococcus pneumoniae, Haemophilus influenzae, and Moraxella catarrhalis were the most commonly isolated pathogens. Others have found similar results for patients with chronic sinusitis.[16-18] Anaerobes were found to be important pathogens by some investigators[19] but not by others.[20,21] Muntz and Lusk[20] found that the most common organisms in the cultures of the contents of 204 ethmoid bullae were α-hemolytic streptococci and Staphylococcus aureus, organisms that normally colonize the nose. They postulated that the cause of chronic sinusitis was obstruction and mucostasis with the overgrowth of colonizing bacteria.

Unusual pathogens may be found in some patients with sinusitis. Pseudomonal sinusitis was found in 89% of patients with cystic fibrosis.[22] In patients with immunodeficiencies, fungal species may be the causative agents.[23]

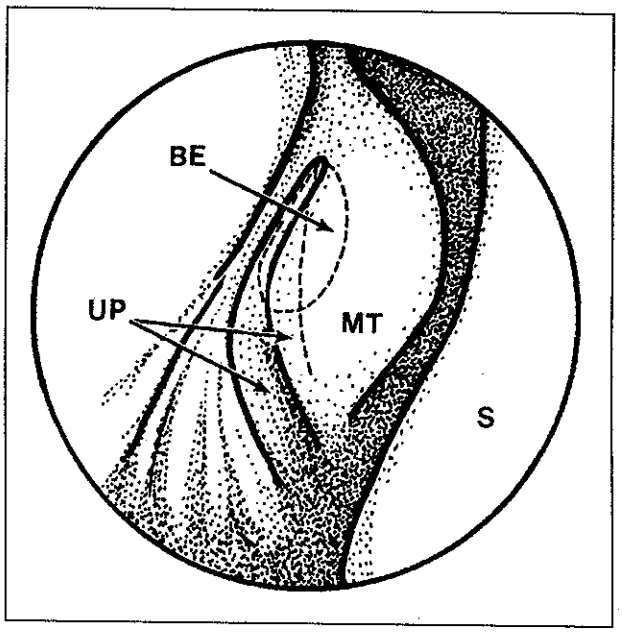

Figure 1. Nasal anatomy of an infant. Before the child is 1 year of age, the bulk of the turbinate functionally excludes the middle meatus from the functional nasal airway. **BE:** Bulla Ethmoidalis, **UP:** Uncinate Plate, **MT:** Middle Turbinate, **S:** Septum.

Diagnosis

The diagnosis of chronic sinusitis in the pediatric population is difficult, because most children are poor historians and because the symptoms and signs are not specific. In infants, irritability may be the only symptom.[1] This may be

the result of the shallow sinuses and wider ostia, which less frequently produce symptoms such as pressure.[13] In older children, the most common symptoms and signs are purulent rhinorrhea, chronic cough, nasal congestion, headaches, and chronic serous otitis media.[24-26] Sinusitis has also been associated with asthma.[13,27,28]

The physical examination of a child's nose is often extremely difficult, and only limited anterior rhinoscopy is tolerated by these young patients. The examination may be accomplished using an otoscope, which affords a view of the middle turbinate and middle meatus. Attempts at flexible and rigid endoscopy with a 4mm telescope are not likely to be successful and may lead to less cooperation during subsequent examinations. The use of 2.7mm telescopes in the evaluation of older children has been reported,[26] but we have not found them valuable even in these patients.

The physical examination is usually less revealing in the child than in the adult. Boggy turbinates, mucopus along the nasal floor, or crusting may be seen in children. Examination of the oropharynx may reveal purulent drainage and enlarged or chronically inflamed tonsils. Concomitant otitis media was seen in 63% of patients younger than 8 years of age in one series.[24] Unlike adults, nasal polyposis is unusual in the pediatric population, with the exception of children with cystic fibrosis. Among 14 patients with cystic fibrosis who underwent FESS for chronic sinusitis, 86% were found to have polyps.[22] Manning stated that there is a 5% to 40% incidence of nasal polyposis in this patient population.

Most patients seen in our practice are referred from pediatricians and pediatric allergists, and they have already been treated with many courses of antibiotics and have been evaluated for allergies. However, in the workup of the child with chronic runny nose and nocturnal cough, another full medical regimen is employed before evaluation with Computed Tomography (CT). Medical therapy includes a 3-week course of ß-lactamase resistant antibiotics and topical nasal steroids. A short course of oral steroids may be prescribed in some cases. Topical vasoconstrictors, such as phenylephrine, are also employed in acute cases, but they are used only for 3 to 5 days. Unless previously performed, an allergy assessment is done. Routine evaluation is not done for immunoglobulin deficiency or immotile cilia syndrome. However, if a history of recurrent pulmonary infections, recurrent polyposis after successful surgery, or systemic disease is elicited, an immunologist may evaluate the child.

After this medical regimen has been completed, radiologic evaluation is performed. The value of plain sinus films in assessing children is questionable, because the results have correlated poorly with the successful diagnosis of chronic sinusitis.[29] Lazar and colleagues[30] found that CT detected sinus disease in 40% of 45 patients who had normal sinus x-ray films. Lusk[31] found that plain films of the sinuses underestimated or overestimated the degree of sinus involvement. Magnetic resonance imaging can help to evaluate a sinus tumor or fungal sinusitis. Some centers have used ultrasonography, but this is of limited value.[15,24]

CT scans more accurately assess the extent of mucosal thickening. We use 4mm coronal and axial cuts at 3mm intervals. These parameters allow accurate assessment of the ostiomeatal complex, the frontal recess area, and the sinuses themselves. April and co-workers[14] found that disease most commonly affected the maxillary and ethmoid sinuses, followed by the posterior ethmoid and frontal sinuses. They found the sphenoid sinus was least frequently involved. They also discovered more extensive disease in patients with histories of asthma, and bilateral uncinate demineralization in patients with cystic fibrosis.

Our approach to diagnosing the pediatric patient with chronic sinusitis integrates the radiologic evaluation with the clinical assessment. For a young patient with a relatively short duration of symptoms and whose symptoms may be partially caused by chronic adenotonsillitis, the initial evaluation is done with plain films. In these patients, who are usually younger than 4 years of age, the adenotonsillar component of the disease process may be significant. They often have a concomitant problem with mouth breathing and snoring and may also have otitis media. This subpopulation of patients may benefit from minimal sinus surgery, such as inferior meatal antrostomy, if concurrent removal of the tonsils and adenoids can eliminate the bacterial reservoir. When the history and physical examination are consistent with this early disease, plain films of the sinuses usually suffice for radiologic confirmation.

In older patients and in those with a more protracted course, disease of the ethmoid sinuses, frontal recess, frontal sinus, and sphenoid sinus is more likely. A coronal CT without contrast is ordered after a trial of optimal and prolonged medical therapy. In most cases, the CT accurately illustrates the extent of disease and delineates any anatomic abnormalities. However, the CT cannot be considered a "crystal ball" for viewing the sinuses. For 10 of 260 pediatric patients who underwent FESS because they had persistent clinical manifestations of sinusitis but normal CT, Lazar and Younis[8] found mucosal disease in all 10 patients (Figure 2). It has also been our experience that CT tends to underestimate the extent of disease. CT findings must therefore be interpreted within the context of the patient's history and the clinical findings.

Treatment

The initial treatment of chronic sinusitis is medical. For patients who respond to the initial medical regimens, prophylactic antibiotics may be used with saline nasal douches.[13] In addition to prophylactic antibiotics, we

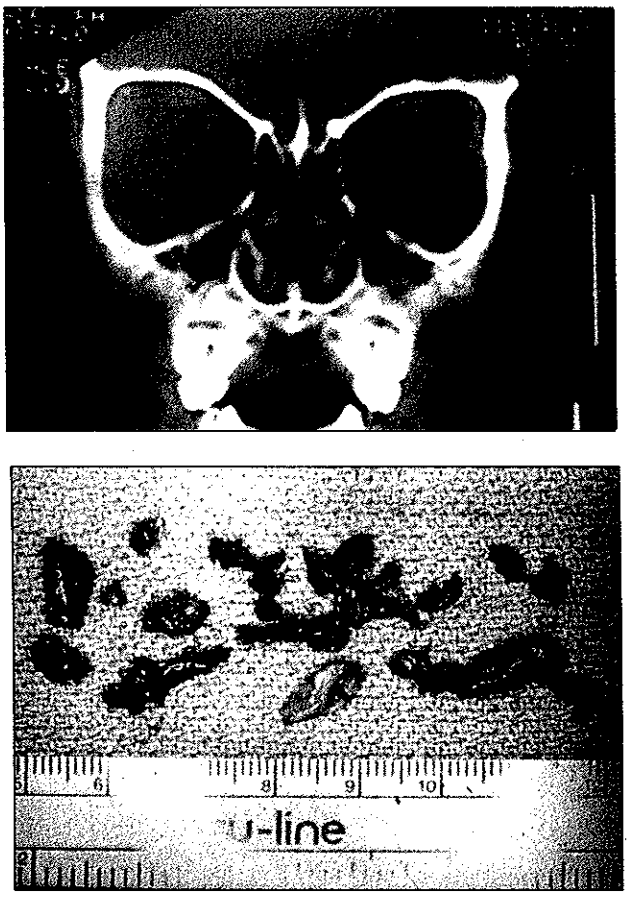

Figure 2. CT scans may underestimate the extent of disease. **Figure 2a.** The CT scan shows the circled area to be free of disease. **Figure 2b.** During surgery, this polypoid material was removed from the same area.

recommend continued use of topical nasal steroid sprays, which can prevent the mucosal swelling that leads to ostial occlusion, subsequent changes in the sinus environment, and bacterial overgrowth. We also recommend routine allergy evaluation (although most patients are referred to our institution after having completed a full allergy assessment). With time, medications may be tapered and, with careful monitoring, acute exacerbations can be recognized and treated early.

For patients who fail to respond to adequate medical therapy, surgical intervention is warranted. Antral lavage may be useful for obtaining material for culture, but it usually does not allow sufficient aeration of the sinus. The use of inferior meatal antrostomy is controversial. Lusk and colleagues[31] reported an improvement rate of only 27% 6 months after surgery for 39 patients undergoing 46 antrostomies. The reason for failure may be a result of the continued flow of the mucociliary blanket toward the natural ostium, the premature closure of the windows, or the ethmoid sinuses not being addressed. However, in some patients in whom the normal mucociliary flow is permanently disrupted (e.g., immotile cilia syndrome, cystic fibrosis), dependent drainage may be valuable.

Our approach to the treatment of chronic sinusitis and to the appropriate role that FESS or inferior meatal antrostomies play is predicated on a multifactorial assessment of the pathophysiology of chronic sinusitis. The interactions among the sinuses, adenoids, tonsils, and ear are complex and must be addressed as a whole (Figure 3). We view surgical intervention as an adjunct to the medical therapy that is directed at the underlying causes of the disease process.

For a very young patient with a relatively short history of sinus complaints (<1 year) but with a history of chronic otitis media and with mucosal thickening and large adenoids demonstrated on plain films, a conservative surgical approach is employed, and may include bilateral myringotomy and pressure equalizing tube placement, adenoidectomy, and/or inferior meatal antrostomies. If there is a history of recurrent adenotonsillitis or pharyngitis and if the tonsils appear enlarged and chronically inflammed, we perform tonsillectomy, adenoidectomy, myringotomy with tube placement, and inferior meatal antrostomies. With this minimal sinus intervention, temporary aeration of the sinus is achieved while medical therapy is used to resolve the sinus inflammation. Removal of a large bacterial pool (i.e., adenoids and tonsils) helps the inflammation in the infundibulum to subside with medical therapy.

This conservative approach does not exclude the very young patient from being a candidate for FESS. If the chronicity and severity of the symptoms dictate, CT is ordered and FESS performed if necessary (Figure 4). In the patient undergoing FESS, the contribution of adenotonsillar disease is assessed and, if indicated, tonsillectomy and adenoidectomy are carried out.

The older patient usually has a longer history of sinus complaints (>1 year). The sinuses are more developed in these patients, and FESS, rather than antrostomy, is the procedure employed to remove diseased sinus tissue.

All FESS is performed under general anesthesia, and we employ a modified Messerklinger technique. Hemostasis is essential during the procedure. In close consultation with a pediatric anesthesiologist who is familiar with otolaryngologic surgery, a 2% solution of Lidocaine with 1:50,000 epinephrine can be safely injected into the surgical site to achieve vasoconstriction. The nose is then packed for 10 minutes with cotton pledgets soaked with a 4% solution of cocaine. The patient is monitored carefully for the development of any arrhythmia.

All surgery for pediatric patients is done with the same instruments used for adult endoscopic procedures. Al-

though the confines of the pediatric nose are smaller, we have not encountered problems with insufficient space for our instruments. Smaller scopes are disadvantageous because of limited lighting and their restricted field of view.

After medialization of the middle turbinate, an uncinectomy is performed. The infundibulum may be quite narrow, shallow, or both, especially in cases of maxillary hypoplasia. Ethmoidectomy is carried out in children as in adults, except that the anatomic distances are smaller. It is usually necessary to explore the frontal recess area. This area may be overlooked and, in our experience, is underdiagnosed using CT. The sphenoid sinus is explored only if sphenoid disease is demonstrated on the CT, which is always displayed during surgery.

Several factors make middle meatal antrostomy difficult in children. The confines of the infundibulum limit access, and the immature pneumatization makes widening the bony ostium difficult. The mucosa is often thickened, predisposing it to detachment from the bony sinus walls during antrostomy. In addition, the large area of mucosa surrounding the natural ostium increases the risk of stripping the mucosa while entering the sinus. We therefore puncture the mucosa just above the superior border of the inferior turbinate, where the sinus mucosa is closely adherent to bone. We have found this method allows successful entrance into the sinus cavity without stripping the mucosa. This opening is then widened to include the natural ostium in the final antrostomy.

The treatment of the middle turbinate is tailored to the needs of the individual patient. Rarely is removal of significant amounts of turbinate needed. However, if severe polypoid degeneration, turbinate bulk, or flaccidity puts the turbinate at risk for adhesions to the lateral wall, careful endoscopic trimming with scissors may be performed.

At the end of the procedure, Depo-Medrol (40 mg/kg) is placed onto the operative site and the ethmoid cavity is filled with Bactroban ointment. If necessary, epinephrine-soaked pledgets are placed in the nose at the termination of the procedure and are removed later in the recovery room.

During the postoperative period, the patient is maintained on antibiotics and topical steroid sprays. If polyposis or mucosal disease is found in the maxillary sinus during surgery, the patient is placed on a short course of oral steroids.

Postoperative office endoscopic examination is extremely difficult in children, except for a few of the oldest and most cooperative patients. All patients are returned to the operating room 2 to 4 weeks after FESS for nasal endoscopy. Some granulation tissue and early adhesions between the middle turbinate and the lateral wall usually are found.[24] The granulation tissue is removed, adhesions are lysed, and all crusts are cleaned. The maxillary antra are irrigated, and Depo-Medrol is again instilled over the operative site.

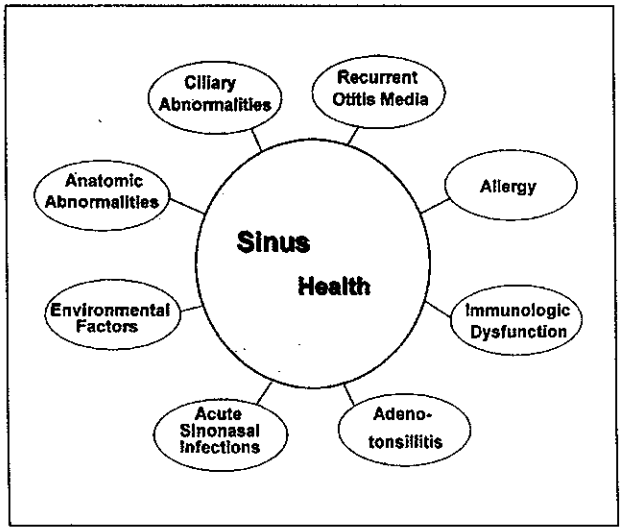

Figure 3. Schematic of the pathogenesis of chronic sinusitis in the pediatric population. Multiple factors interplay, and some of these, including the effects of chronic adenotonsillitis, adenotonsillar hypertrophy, and otitis media, are more prevalent in children.

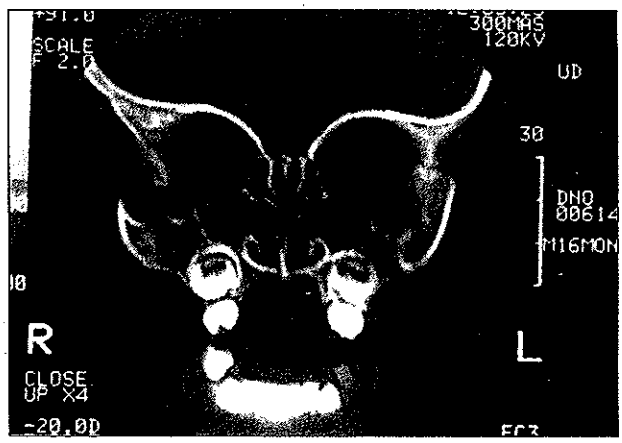

Figure 4. CT scan of a 16-month-old child with chronic sinusitis. The disease in the ethmoid air cells is unlikely to resolve with conservative therapy. Despite the child's young age, endonasal sinus surgery is necessary to remove the chronically inflammed ethmoidal mucosa.

After endoscopy, the patients are continued on the topical steroids and started on nasal irrigation. Saline sprays are used by younger patients, and for those who can cooperate, Alkalol nasal douches are prescribed. Oral steroids are not routinely employed after endoscopy, un-

less extensive polypoid mucosal degeneration is found during the procedure. If immunoglobulin deficiency has been diagnosed, intravenous therapy with immunoglobulin and prophylactic antibiotic treatment may be instituted by the immunologist. Patients are seen at 1- to 2-week intervals for the first 6 weeks and then examined less frequently, as dictated by their clinical status.

The overall success rates for FESS in children is 80%,[8,24,26] which is similar to the success rate for adult patients.[32,33] The success of surgery can be difficult to assess, but it has been accomplished by using patient and caretaker questionnaires. Reporting the results for 513 adults and 260 children, Lazar and Younis[8] found improvement of nasal obstruction in 85%, of cough in 86%, of nasal discharge in 83%, and of headaches in 84%. The number of missed school days, degree of asthmatic symptoms, and amount of antibiotics have also diminished after FESS. Standardized methods for assessing the efficacy of FESS have not yet been reported, although they are being investigated.

The complication rate for FESS is about the same as that for nonendoscopic techniques.[34] We have experienced no major complications, and the minor complication rate has been favorable. The most often encountered problems were synechiae, persistent or recurrent polyposis, and bleeding.

Revision FESS may be necessary for some patients. When indicated, it is usually performed within 1 year of the initial surgery. We have ascertained that the most common finding in revision FESS is significant adhesions of the middle turbinate to the lateral nasal wall, resulting in ostiomeatal complex occlusion, and narrowing of the ostium. Judicious trimming of the middle turbinate if it is large, polypoid, or flaccid and the use of wide middle meatal antrostomies decrease the risk of these problems. Depending on the patient's history and the aggressiveness of the disease, a biopsy of the tracheobronchial tree during revision surgery may be performed to rule out immotile cilia syndrome. The results of revision surgery mirror those of the initial surgery and improve the overall efficacy of this procedure.[8,35]

Conclusion

Chronic sinusitis is the result of complex interactions of the anatomy and function of the sinuses within the context of the entire upper aerodigestive tract. There is still much to learn about the interdependence of the sinuses and the lymphoid tissue of Waldeyer's ring. The appropriate role of antrostomies, adenoidectomy, and tonsillectomy in the total treatment of chronic sinusitis must still be determined.

Treatment of chronic sinusitis requires a team approach involving the pediatrician, allergist/immunologist, pediatric infectious disease specialist, and otolaryngologist. Along with aggressive medical management, FESS has greatly improved the condition of most patients undergoing the procedure and has been shown to be safe and cost effective for treating children.

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