

TITLE: Pediatric Endoscopic Sinus Surgery

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Purpose

Sinus disease is a very common source of morbidity for many children. On average, children average 6-8 upper respiratory tract infections per year. 5-13% of all URIs are complicated by secondary bacterial infection of the paranasal sinuses. Young children are unable to communicate some of the symptoms of sinusitis such as headache, nasal obstruction, and sinus pain/pressure. This may pose a diagnostic challenge to clinicians who must rely on parental reporting of symptoms and physical findings. The purpose of this Grand Rounds is to explore the evidence available investigating pediatric FESS to determine its indications, safety, and long-term efficacy. A focus is kept on the management of chronic rhinosinusitis in the pediatric population.

History

Pediatric endoscopic sinus surgery was first performed in the late 1980s with reported short term success over 80%. The initial surgical indications were broad. Indications for adult FESS were sometimes used in the pediatric population, without evidence-based data. Initial studies of pediatric FESS were often retrospective, without a comparison to medically treated or non-treated group. A paradigm shift occurred when prospective studies indicated that medical therapy was an effective approach to treatment in chronic rhinosinusitis (CRS) in the pediatric population. Additionally, research in animals revealed that sinus surgery may have a significant effect on the developing facial skeleton. Recent studies have conducted using an evidence-based approach to pediatric sinus disease that includes FESS as an option.

Indications for Endoscopic Sinus Surgery in Children

In 1998, a consensus panel in Belgium determined guidelines for FESS in children. There were 9 indications listed: complete nasal obstruction in cystic fibrosis caused by massive polyposis or closure of the nose by medialization of the lateral nasal wall, antro-choanal polyps, intracranial complications of sinus disease, mucoceles and mucopyoceles, orbital abscesses,

traumatic injury to the optic canal, dacryocystorhinitis secondary to sinusitis, fungal sinusitis, and some meningo-encephaloceles. A possible indication listed was CRS refractory to medical management. An additional indication found in recent literature utilizing FESS is for surgical resection of anterior skull-base tumors including juvenile nasopharyngeal angiofibroma.

CRS in Children

CRS was listed as a possible indication for pediatric FESS in the consensus meeting. CRS usually carries a multifactorial etiology. This disease process is due to an insult to normal drainage pathways of the paranasal sinuses leading to stasis of secretions and secondary overgrowth of microorganisms. Recurrent URIs change the normal mucosal thickness as well as impairing normal mucociliary clearance of secretions. In the daycare setting or in environments with multiple children, the pediatric population is at risk of acquiring recurrent URIs. Additionally, children raised in households that smoke tobacco tend to have greater incidences of sinus and middle ear disease.

Allergic rhinitis, asthma, aspirin allergy, and atopy may contribute to the development of CRS. Allergic rhinitis is reported to be present in up to 40% of people at some point in childhood. It is also associated with up to 80% of cases of CRS. Allergic rhinitis, asthma, aspirin, and atopy may be present in the family of children with CRS. Additionally, serologic or skin testing for potential allergens should be considered in all children with CRS.

Adenoid hypertrophy may obstruct the nasopharynx, thus preventing the normal clearance of secretions resulting in stasis and possible infection. Structural abnormalities, such as choanal stenosis/atresia, severely deviated septum, large obstructive agger nasi air cells, hypoplastic maxillary sinuses and bony remodeling due to active sinus disease processes may obstruct normal clearance of secretions. A CT scan of the sinuses may be helpful in addition to endoscopic findings in diagnosing these structural abnormalities.

Gastroesophageal reflux disease (GERD) has also been associated in children with CRS. One study discovered that 19 of 30 patients with CRS had tested positive for GERD by pH probe study. 79% of these patients showed improvement after medical and behavioral therapy for reflux. Another study found that 25 of 28 children who were candidates for FESS due to sinusitis were able to avoid surgery with a regimen of a proton-pump inhibitor (PPI) and behavior modification. Empiric therapy with a PPI with or without a prokinetic agent and behavior modification is an acceptable approach for treating children with CRS suspected to be due to reflux.

Immunologic deficiency, cystic fibrosis, and ciliary dyskinesia pose a significant problem to treatment of CRS. Recurrent and chronic infections that respond poorly to medical therapy should warrant further immunologic workup in a child. Quantitative (antibody titers) and qualitative (T-cell function) immunologic testing should be considered in these children. Additionally, recurrent upper and lower respiratory tract infections should lead to further testing. A mucosal ciliary biopsy may be necessary to diagnose ciliary dyskinesia. A sweat chloride test should be performed in all children with sinonasal polyps to investigate for cystic fibrosis.

Allergic fungal sinusitis (AFS) is a unique pathologic process that may result in severe sinus disease. It is caused by a hypersensitivity response to fungi in the paranasal sinuses. *Aspergillus*, *Alternaria*, *Bipolaris*, *Culvularia*, and *Drechslera* are some of the common fungi known to cause AFS. In addition to the sinus symptoms of CRS, children may have facial abnormalities such as proptosis due to bony remodeling of the facial skeleton. Charcot-Leydon crystals, degranulated eosinophils, and the presence of fungal hyphae are diagnostic findings on microscopic examination of the (“peanut butter”) sinonasal debris or allergic mucin removed from patients with AFS. CT findings may reveal significant sinonasal obstruction with double-density and significant bony remodeling with possible cranial or orbital extension.

Acute Bacterial Sinusitis

In order to understand CRS, the management of acute sinusitis must be discussed. In 2001, Clinical Practice Guideline for the management of sinusitis in children was published in *Pediatrics*. Different forms of sinusitis were also defined:

- Acute bacterial sinusitis (ABS): bacterial infection of the paranasal sinuses lasting less than 30 days in which symptoms resolve completely.
- Subacute bacterial sinusitis: bacterial infection of paranasal sinuses lasting between 30-90 days in which symptoms resolve completely.
- Recurrent acute bacterial sinusitis: episodes of bacterial infection of the paranasal sinuses, each lasting less than 30 days and separated by intervals of at least 10 days during which the patient is asymptomatic.
- Chronic sinusitis: episodes of inflammation of the paranasal sinuses lasting more than 90 days. Residual respiratory symptoms persist such as rhinorrhea, nasal obstruction, or cough.
- Acute bacterial sinusitis superimposed on chronic sinusitis: patients with residual respiratory symptoms develop new respiratory symptoms. When treated with antimicrobials, the new symptoms resolve, but underlying residual symptoms persist.

The recommendations made in this guideline were for management of ABS. Antibiotics were recommended to achieve a more rapid clinical cure. Children with uncomplicated ABS mild to moderate severity not attending daycare are recommended to be treated with either amoxicillin 45 mg/kg/d in 2 divided doses or 90 mg/kg/d in 2 divided doses. For penicillin allergic patients, cefdinir (14 mg/kg/d in 1-2 doses), cefuroxime (30 mg/kg/d in 2 doses), cefpodoxime (10 mg/kg/d 1 dose), clarithromycin (15 mg/kg/d 2 doses), or azithromycin (10 mg/kg/d on day 1, and 5 mg/kg/d for 4 days) are recommended.

If symptoms are severe, or refractory usual amoxicillin or other antimicrobial, or daycare is attended high-dose amoxicillin-clavulanate (80-90 mg/kg/d in 2 doses) or IM ceftriaxone (50 mg/kg single dose) followed by oral therapy is recommended. Duration of therapy may be 10, 14, 21, or 28 days but an alternative suggestion is 7 days of therapy beyond resolution of symptoms.

For cases of failure of cure following oral antibiotics, IV cefotaxime or ceftriaxone are recommended. A maxillary sinus aspiration may also be appropriate to determine the microbial species present and determine the antibiotic sensitivities. Children with complicated or

suspected complications of ABS should be treated promptly and aggressively and have appropriate consultations with an otolaryngologist, infectious disease specialist, ophthalmologist, and neurosurgeon. IV ceftriaxone (100 mg/kg/d in 2 doses) or ampicillin-sulbactam (200 mg/kg/d in 4 doses) should be started empirically and a maxillary sinus aspiration should be attempted. Vancomycin (60 mg/kg/d in 4 doses) may be used for cases of suspected methicillin-resistant *Staphylococcus aureus* or for patients with severe penicillin allergy. A CT scan is also recommended to determine possible intracranial or orbital involvement such as an epidermal or subperiosteal abscess which may not be easily diagnosed on physical findings of a young ill child.

The Role of Antibiotics in CRS

In 2001, Don published a study that recommended a stepwise protocol for the management of CRS in children. The purpose of this study was to evaluate the efficacy of IV antibiotics for treatment of CRS in children. This was a retrospective study of 70 patients with a diagnosis of CRS without cystic fibrosis, immunologic deficiencies, nor facial anatomic abnormalities with ages ranging from 10 months to 15 years. All patients had at least 12 weeks of CRS symptoms with persistent sinus disease present on CT after 3-4 weeks of oral antibiotics. All patients underwent maxillary sinus aspiration and irrigation with selective adenoidectomy depending on presence of adenoid hypertrophy on CT or intraoperative findings during maxillary sinus aspiration and placement of long-arm IV catheter. All patients also underwent a 1-4 week course of (culture-directed when possible) IV antibiotics. Interestingly, 73% of patients had at least one organism present on culture with *H. influenzae* being the most common pathogen present. 43% of patients had multiple organisms on aspiration. The antibiotics used for treatment were cefuroxime (43%), Unasyn (31%), ticarcillin with clavulanate (21%), ceftriaxone (3%), and vancomycin (1%). 66% of patients also had a course of oral antibiotics following completion of IV therapy. 10% of patients were reported to have relatively minor complications without any mortality.

An important finding of this study was that 89% of patients had initial improvement after IV antibiotic therapy. Of these, 74% had long term follow-up between 6 to 62 months (mean 25 months). In this group with long term follow-up, 88% were reported to have long term improvement by the parents of the children. 12% did not have long-term improvement, but also did not require FESS. In the group with long term follow-up, 23% had no further episodes of sinusitis, whereas, 77% had subsequent episodes of sinusitis, but were reported to be completely resolved following oral antibiotic therapy. There was no reported difference in this group with improvement treated with concomitant adenoidectomy versus without adenoidectomy. 11% of patients in this study did not have initial improvement following IV antibiotics and required FESS. Of those requiring FESS, 88% had long-term follow-up. 43% had long-term improvement.

A protocol was proposed by Don et. al from this study for children with CRS with symptoms 12 weeks duration or longer refractory to 3-4 week treatment with oral antibiotics. First, they recommended an allergy and immunology assessment with appropriate medical management for those found to have abnormalities. For patients who were found to have no evidence of allergic or immunologic disease and for patients refractory to medical management of these processes, a CT scan of the paranasal sinuses was deemed appropriate as the next step.

For those with an anatomic abnormality leading to sinus pathology, FESS was proposed. For those with positive findings of sinusitis without specific anatomic abnormalities, bilateral maxillary sinus lavage with culture directed IV antibiotics and selective adenoidectomy was proposed. If there was no improvement, FESS was then deemed necessary.

This study indicated that medical management of pediatric CRS refractory to oral antibiotics is effective and relatively safe. FESS may be reserved for those patients refractory to IV antibiotics. However, this study also had some limitations. It was a retrospective review of patients and there was no stratification for severity of symptoms. The questionnaire used in this study was not reported to be a validated questionnaire for reporting symptoms by the parents of the children investigated. Additionally, there was no standardized analysis of the CT findings of the patients. The role of adenoidectomy could not be assessed in this population as another therapeutic option in the management of CRS in children. Lastly, the role of topical steroids, saline irrigations, and antihistamines was not assessed. The data from this study is nonetheless quite useful in attempting to manage CRS in children.

The Role of Adenoidectomy in CRS

Adenoid hypertrophy is not an uncommon finding in children. Adenoid hypertrophy may lead to obstruction of the Eustachian tube as well as obstruction of the nasopharynx resulting in stasis of paranasal sinus secretions. Additionally, adenoid tissue has been found to be a reservoir for pathogenic bacteria. Stasis of secretions along with the presence of bacteria may result in sinusitis. Previous studies have indicated the efficacy of adenoidectomy in the treatment for chronic otitis media with effusion. Additionally, the overall success rate for adenoidectomy in the treatment of CRS in children has been documented to be about 50%.

A study was conducted by Ramadan in 2004 to evaluate the success of FESS alone, adenoidectomy alone, and FESS with adenoidectomy as surgical options for children with CRS refractory to medical management. This was conducted as a prospective non-randomized study over 10 years and follow-up assessment at 12 months. The results of this study were that success rates were 87.3%, 75%, and 51.6% in the FESS with adenoidectomy, FESS alone, and adenoidectomy alone groups, respectively. Revision rates were 7.6%, 12.5%, and 25%, respectively. Multivariable analysis was performed using logistic regression model.

The success rate of surgery was noted to be 59.5% for children 6 years or younger. This was significantly lower than children over 6 years who had a success rate of 84%. Children over the age of 6 years who underwent FESS with adenoidectomy had the best success rate 96%, which was significantly higher than FESS alone (79%) and adenoidectomy alone (67%). Success rates were not significantly different for FESS with adenoidectomy (76%), FESS alone (67%), and adenoidectomy alone (44%) in children 6 years and under. In asthmatics within this study (43.2%), success after surgery was found to be 62% compared to 80% for children without asthma. The success rate for asthmatics that underwent FESS with adenoidectomy (82%) was not significantly different from FESS alone (77%), but both groups were significantly better than adenoidectomy alone (37%). In non-asthmatics, success with FESS with adenoidectomy was 90% but this was not significantly different from the FESS alone group (79%), but was significantly better than adenoidectomy alone group (65%). For the children exposed to smoke (27%), success after surgical therapy was not significantly different from the group not exposed

to smoke, 67% and 74%, respectively. For children exposed to smoke, FESS with adenoidectomy had greater success (82%) compared to FESS alone (64%) and adenoidectomy alone (46%). An additional variable analyzed in this study was severity of disease based upon Lund-McKay CT score. For patients with Lund McKay score greater than 4, they had greatest success when FESS with adenoidectomy was performed compared to FESS alone and adenoidectomy alone (87%, 72%, and 46% respectively). In children with scores of 4 or less, there was no significant difference (90%, 100%, and 59%). 47% of children in this study had allergies, and overall success after surgery for those with allergies was similar to those without allergies (74% and 71%, respectively). There were few surgical complications. 2.9% had minor orbital complications involving orbital entry and postoperative orbital ecchymosis without any complaints. No postoperative CSF leaks, bleeding, or lacrimal duct injuries were found.

This study provided an insight into the best surgical intervention to perform in children with CRS refractory to medical management based upon severity of disease and age. Children with asthma exposed to smoking had least benefit from adenoidectomy alone, but a greater success when FESS was performed in addition to adenoidectomy. Children over 6 years with Lund-McKay score greater than 4 had a better outcome when FESS with adenoidectomy was performed. A conservative approach for children age 6 and younger with a Lund-McKay score 4 or less without asthma may be with an adenoidectomy alone as the initial procedure.

Quality of Life After Surgical Therapy for Sinus Disease

A prospective, nonrandomized quality of life (QOL) study was conducted by Rudnick in 2006 using the validated SN-5 QOL survey completed by caregivers of children following surgical therapy for sinonasal disease. Adenoidectomy (59%) and FESS (41%) were performed in these children with preoperative SN-5 assessment as well as second assessment 6 months after surgery. This study revealed that all children had significant improvement after surgical intervention and there was no significant difference in QOL scores between children undergoing adenoidectomy versus FESS.

Accuracy of CT Finding in CRS in Children

Although CRS is a clinical diagnosis, CT findings are important in diagnosis. In 2004, Bhattacharyya et al. conducted a prospective study to determine the diagnostic accuracy of CT in pediatric CRS using the Lund-McKay score. Two cohorts were followed: one undergoing a preoperative CT for planning of FESS with known cystic fibrosis or anatomic abnormalities, and the other group undergoing CT for non-sinusitis reasons. This study revealed an average Lund-McKay score of 10.4 in the group with sinus disease and 2.8 in the group without clinical sinus disease. This revealed that incidental paranasal mucoperiosteal thickening in the absence of clinical symptoms is present in the pediatric population. When a score of 5 is used to represent true sinus disease, CT scan demonstrated a sensitivity of 86% and specificity of 85%.

CRS, Age and Sinus Surgery

In order to understand the appropriate management of CRS in children, recognition of successful surgical management and age at intervention must be discussed. A cohort study was performed by Ramadan in 2003 to determine the relationship of age to outcome after FESS in

children. A questionnaire was completed by caregivers 12 months after FESS with selective adenoidectomy for CRS for assessment of symptoms. This study revealed that children 6 years and older had 89% success, whereas, children under 6 years had 73%. Additionally, 9% that required revision surgery were under 6 years. After age stratification, children under 4 years had 35% success, children 4-8 years had 88% success, and children over 8 years had 86% success. This study also found that children under 3 years had the highest failure rate with 75% requiring revision surgery. Some of the results of this study are difficult to apply to a larger population as there was a small patient population in the younger age groups. However, this study does indicate that older children tend to have better outcomes after FESS compare to younger children with CRS. This may provide insight into management of younger children with perhaps more emphasis on medical therapy.

FESS and Facial Growth

During the early years of pediatric FESS, concern was raised regarding the effects of surgery on the developing facial skeleton. Animal studies indicated significant detrimental effects when sinonasal surgery was performed on young rabbits and piglets. In one study, unilateral sinus surgery was performed on piglets with subsequent evaluation of development based on CT finding. This study revealed that on the operated side, maxillary and ethmoid sinuses only reached a fraction the size of the non-operated side (57% and 65%, respectively). Earlier studies of cleft palate surgery and its effects on maxilla growth revealed a greater incidence of midfacial maldevelopment after cleft palate repair. Another study of pediatric mandibular fractures revealed significant asymmetry after repair in children.

Wolf published a study of 124 children treated with FESS for CRS revealing no clinically significant disturbance in facial bone development. However, only 4% of patients were under 5 years during the most rapid period of growth of the paranasal sinuses. In 1996, a study revealed that maxillary sinus hypoplasia may be a consequence of endoscopic sinus surgery, but there was no clinically apparent facial asymmetry.

A study by Senior et al. in 2000 evaluated the quantitative impact of pediatric sinus surgery on facial growth and development. The study group consisted of children requiring unilateral sinus surgery for periorbital or orbital sinusitis. The control groups were adults without evidence of sinusitis on CT and adults with findings of sinusitis on CT and clinical history of childhood sinus symptoms. This study had a mean follow-up of 6.9 years and found that there was no significant difference in sinus volumes amongst the groups.

A well-known study by Bothwell et al. in 2002 investigated the long-term outcome of facial growth after FESS. This was a retrospective study utilizing anthropometric analysis of 12 facial parameters and qualitative analysis of Caucasian children diagnosed with CRS who underwent FESS versus children with CRS who did not have FESS and normal controls. 10 year follow-up was reported in the study. The Pediatric Rhinosinusitis CT Scoring System was used to determine severity of disease based upon CT findings. The results of this study revealed no significant difference for anthropometric measurements among the groups. Interestingly, on qualitative evaluation by a blinded observer, the non-surgical group had a lower score than the group treated with FESS.

A recent prospective study by Peteghen et al. in 2006 revealed that there was no significant difference in cephalometric parameters among children with cystic fibrosis who underwent FESS compared to normal age-matched controls. These studies indicate that FESS does not significantly alter the normal growth and development of the pediatric facial skeleton. However, it is important to understand that FESS during rapid growth of the facial skeleton had not been thoroughly investigated, and may result in asymmetry.

Safety and Efficacy of Pediatric FESS

Surgical interventions in the pediatric population must be safe and effective to be appropriate option. The safety and efficacy of FESS in adults is well-documented. In 1998, a meta-analysis was published by Hebert investigating the outcomes of FESS. 8 articles with 832 patients met the inclusion criteria, and the publisher included 50 previously unpublished patients from the home institution. A positive outcome of FESS was found to be 88.7% with a mean follow-up of 3.7 years. Additionally, the major complication rate was found to be 0.6% in 6 of the 8 articles included. Blood transfusion requirement and meningitis were the reported complications.

Image-Guided Pediatric FESS

With the advent of image-guided surgery, the ability to perform complex and delicate procedures in the paranasal sinuses has been enhanced. Identification of obscured landmarks may be difficult in disease states. Indications for computer-assisted endoscopic sinus surgery are revision surgery; distorted anatomy of development, postoperative, or traumatic origin; extensive sino-nasal polyposis; pathology involving the frontal, posterior ethmoid, and sphenoid sinuses; disease abutting the skull base, orbit, optic nerve, or carotid artery; cerebrospinal fluid rhinorrhea or conditions where there is a skull-base defect; benign and malignant sino-nasal neoplasms; and choanal atresia. In children, due to smaller and less distinct structures that may not provide adequate identification of critical structures such as the lamina papyracea and skull-base, image-guidance is an asset to surgeons.

Conclusion

Pediatric sinus disease is sometimes a challenging process for clinicians. Patients, parents, and caregivers seek medical assistance for management of sinusitis. The role of the clinician is to provide the best recommendations and options available based upon the evidence presently available. Pediatric FESS has undergone much debate in the otolaryngologic society. Questionnaires sent to pediatric otolaryngologists provide an insight into the contemporary management trends for this process, but do not necessarily reflect the data available in studies. Further research in this area is needed to understand the long-term success and a more comprehensive understanding of when FESS should be performed in the setting of CRS.

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