Pediatric chronic sinusitis: diagnosis and management

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Purpose of review
Review the diagnosis and management of pediatric chronic sinusitis given recent advances in both surgical and medical management

Recent findings
Balloon catheter dilation (BCD) of the sinuses has been used as an adjunct to adenoidectomy or in lieu of traditional endoscopic sinus surgery. BCD has been shown to be a safe technique in children although its efficacy compared to maxillary sinus irrigation or traditional sinus surgery cannot be determined based on current studies.

Summary
New advances in BCD and biologics may serve as useful adjuncts in surgical and medical therapy respectively with additional research needed to better delineate the optimal indications for each in the treatment continuum.

Keywords
adenoidectomy, biologic therapy, endoscopic sinus surgery, pediatric chronic sinusitis

INTRODUCTION

Pediatric chronic rhinosinusitis (CRS) is an inflammatory disease involving the nose and paranasal sinuses. Compared to adult CRS, relatively little is known about the prevalence and healthcare burden associated with pediatric CRS. In the ambulatory setting from 2005 to 2012, 5.6 million visits annually were attributed to CRS among patients age 0–20 which accounted for 2.1% of all diagnoses during this period [1]. In comparison, over this time period 2.6% of diagnoses were for allergic rhinitis (AR) and 6.7% for otitis media.

DIAGNOSIS

The diagnosis of pediatric CRS is made by the presence of two or more of the following symptoms: nasal obstruction, facial pressure/pain, purulent rhinorrhea, or cough for at least 12 weeks [2]. It should be noted that the addition of cough as a diagnostic criteria in pediatric CRS differs from that of adult CRS. Additionally, one objective clinical sign such as mucosal edema, purulent drainage or nasal polyps must be observed endoscopically and/or computed tomographic (CT) evidence of sinus mucosal thickening or ostiomeatal complex opacification must be present.

PATHOPHYSIOLOGY OF PEDIATRIC CHRONIC RHINOSINUSITIS

Current literature proposes that pediatric CRS is the common presentation of a complex set of disease processes. Multiple factors have been linked to the development of pediatric CRS, however, the pathogenesis of this disease is not well understood. The predominant theory is based on the observation that children usually experience 3–8 viral upper respiratory tract infections (URTI) per year. Viral URTI have been shown to precede ethmoid and maxillary sinus mucosal thickening on CT with 2% progressing to acute bacterial rhinosinusitis and likely contributing to the development of CRS [3].

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KEY POINTS

- Despite the risk of radiation, CT is the imaging modality of choice for the evaluation of paranasal sinus disease because it is very sensitive at detecting mucosal inflammation and Sinus Xrays are not recommended.
- Surgical interventions including adenoidectomy, balloon sinus dilation and/or endoscopic sinus surgery are indicated for pediatric patients with chronic rhinosinusitis who do not respond to medical therapy.
- The role and timing of biologic medication in treatment of pediatric chronic rhinosinusitis has not yet been established.
- Evidence for treatment options in pediatric chronic rhinosinsusitis continues to lag that of adult chronic rhinosinusitis.

BACTERIOLOGY

The most commonly cultured organisms in pediatric CRS include *Streptococcus pneumonia*, *Haemophilus influenzae*, Moraxella catarrhalis, *Staphyloccocus aureus*, and alpha-hemolytic streptococci which have been used to guide empiric antibiotic therapy [4,5]. However, oftentimes cultures may be helpful and have been recommended in patients not responding to empiric treatment by the consensus statement of the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) and European Position Paper on Rhinosinusitis and Nasal Polyps (EPOS) [2,6]. The benefits of culture-guided therapy must be weighed against the decreased tolerance for office-based cultures, with some children requiring sedation. Although maxillary sinus aspiration is the gold standard, it usually requires sedation. In older children who can tolerate office endoscopy, middle meatal cultures may be an advantageous approach. Hsin showed that 78% of middle meatal cultures correlated with maxillary sinus aspirates with a sensitivity of 75% and specificity of 89% [7]. However, in children requiring general anesthesia, maxillary sinus aspiration is preferred since sinus irrigations can be performed concurrently [6].

NASAL ENDOSCOPY

An examination of the nasal cavity can be performed by anterior rhinoscopy or endoscopy to assess the quality of nasal mucosa and the presence of purulent drainage. Although generally well-tolerated, anterior rhinoscopy often provides a limited view of the middle meatus and inferior turbinate. A nasal endoscopy should be performed in all children able to tolerate it for improved visualization of the middle meatus, sphenoethmoid recess, and adenoids or nasopharynx [2,6]. Nasal polyps are uncommon in children and should prompt suspicions of cystic fibrosis (CF) or allergic fungal rhinosinusitis. Antrochoanal polyps are more commonly seen in pediatrics but are typically unilateral and isolated (Fig. 1).

SYSTEMIC DISEASES

Pediatric CRS may present as the sole indicator of a systemic disease or overlap in presentation with coexisting diseases with similar symptoms. Persistent CRS despite satisfactory medical and/or surgical therapy should prompt further work-up and evaluation. For example, CF and primary ciliary dyskinesia (PCD), which cause poor mucociliary clearance, often present with CRS in more than 70% of both

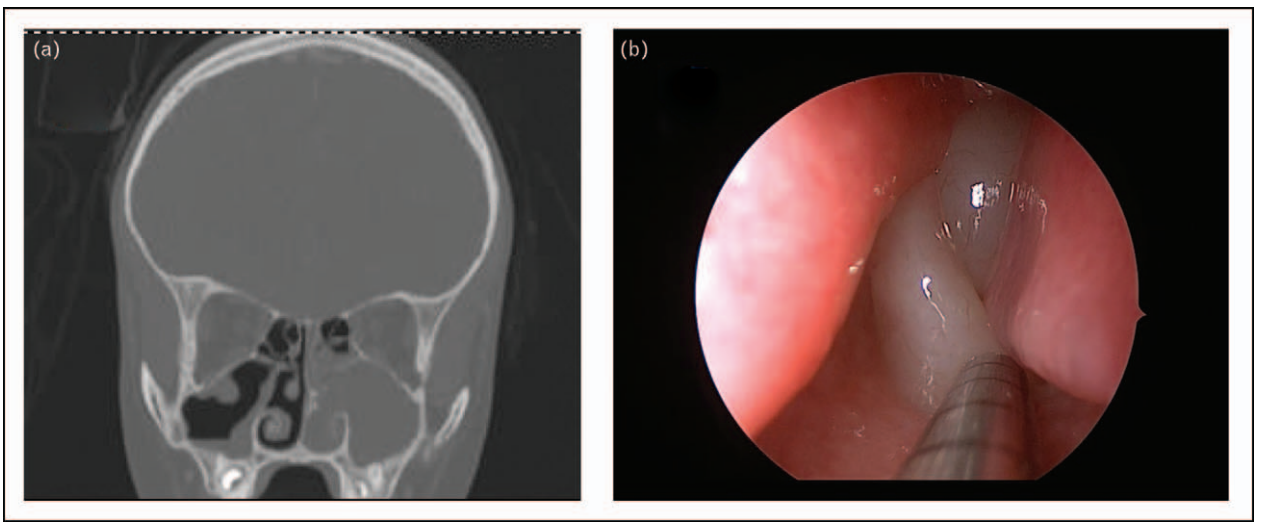

FIGURE 1. 8-year-old patient presenting with antrochoanal polyp seen on CT (a) and endoscopy (b) extending from the left maxillary sinus.

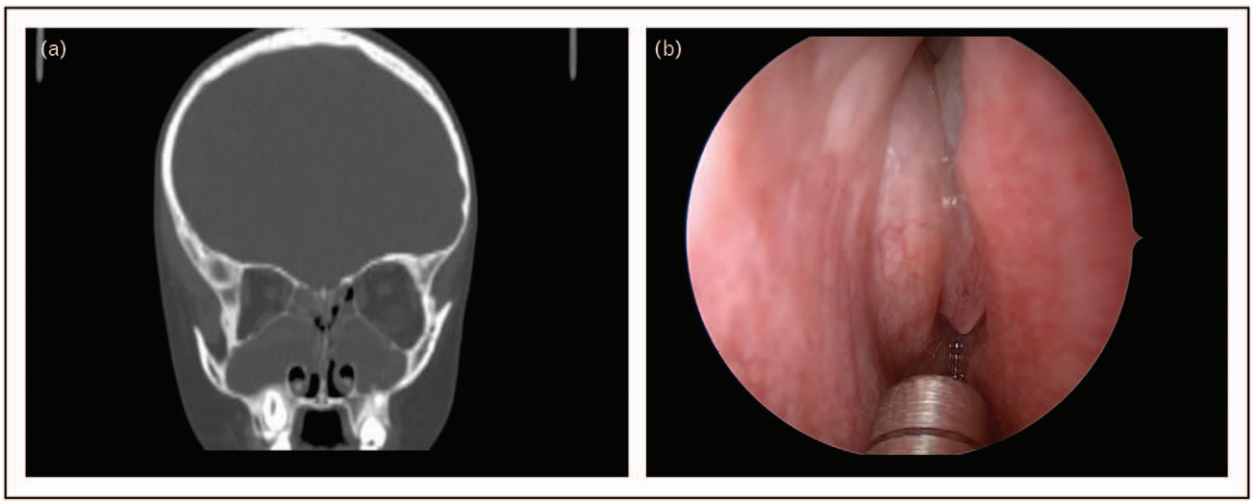

FIGURE 2. 9-year-old with cystic fibrosis seen on imaging with medialization and demineralization of the uncinate (a) with polyps in the left middle meatus on endoscopy (b).

patient populations, although CRS is unlikely to be the only presenting symptom [8,9]. CF can be diagnosed by elevated sweat chloride or genetic testing, although newborn genetic screening for CF is standard in the United States (Fig. 2). Because PCD is genetically heterogenous, diagnosis is challenging and often delayed, with a median age of diagnosis of 5 years [10]. The American Thoracic Society recommends screening with nasal nitric oxide levels, followed by confirmatory genetic testing, with or without transmission electron microscopy evaluation of ciliary ultrastructure [11].

CRS may also be the presenting symptom in humoral immunodeficiencies such as Common Variable Immunodeficiency and X-linked hyper-Immunoglobulin M syndrome [12]. A meta-analysis of CRS patients found immunoglobulin deficiencies in 23% of patients with persistent CRS despite successful sinus surgery [13]. Other humoral immunodeficiencies associated with CRS include Selective IgA Deficiency, IgG Subclass Deficiency, and Specific Antibody Deficiency. Evaluation for antibody deficiencies relies on a detailed clinical history and physical exam to guide laboratory testing, which may include complete blood counts and quantitative immunoglobulin levels. Low levels of antibodies specific to polysaccharide vaccines such as the *S. pneumonia* or *H. influenzae* may also suggest a humoral immunodeficiency [14].

Severe, minimally responsive CRS may also be a manifestation of granulomatous diseases including granulomatosis with polyangiitis (GPA, formerly Wegener's), eosinophilic granulomatosis with polyangiitis (EGPA, formerly Churg-Strauss), or sarcoidosis. Both GPA and EGPA are vasculitides that affect small- and middle-sized vessels and can present with pulmonary and renal involvement. Specific diagnostic criteria for both diseases have been defined by the American College of Rheumatology and include a combination of clinical symptoms, chest imaging abnormalities, and/or tissue biopsy findings [15]. If treatment is planned for suspected sarcoidosis, the diagnosis must first be confirmed with biopsy and pathologic evidence of noncaseating granulomas [16].

Allergic fungal sinusitis is an allergic reaction to environmental fungi which is Type 1 IgE mediated. It is marked by nasal polyps, eosinophilic mucin, and noninvasive fungus on pathology. It is most often unilateral, but can be seen bilaterally (Fig. 3).

More commonly, CRS may coexist with asthma and/or AR, although the association specifically with AR remains controversial. Some have suggested that all three diseases are connected, referring to a "unified airway model'' [17,18]. In support of this hypothesis, studies have shown higher rates of asthma among CRS patients than among the general population [19,20]. Similarly, some studies have shown higher rates of AR among CRS patients, but others have shown rates of AR comparable to the general population [19,21–23,24]. Importantly, although the diagnosis of AR is clinical, previous studies often used different objective measures such as skin prick testing, IgE serology, or radioallergoimmunosorbent testing to define allergy in patients, leading to significantly different estimates of AR prevalence [12,19]. Regardless, evaluation of CRS should include consideration for both asthma and AR as possible comorbid diseases

DIAGNOSTIC IMAGING

CT is the imaging modality of choice for the evaluation of paranasal sinus disease because it is very

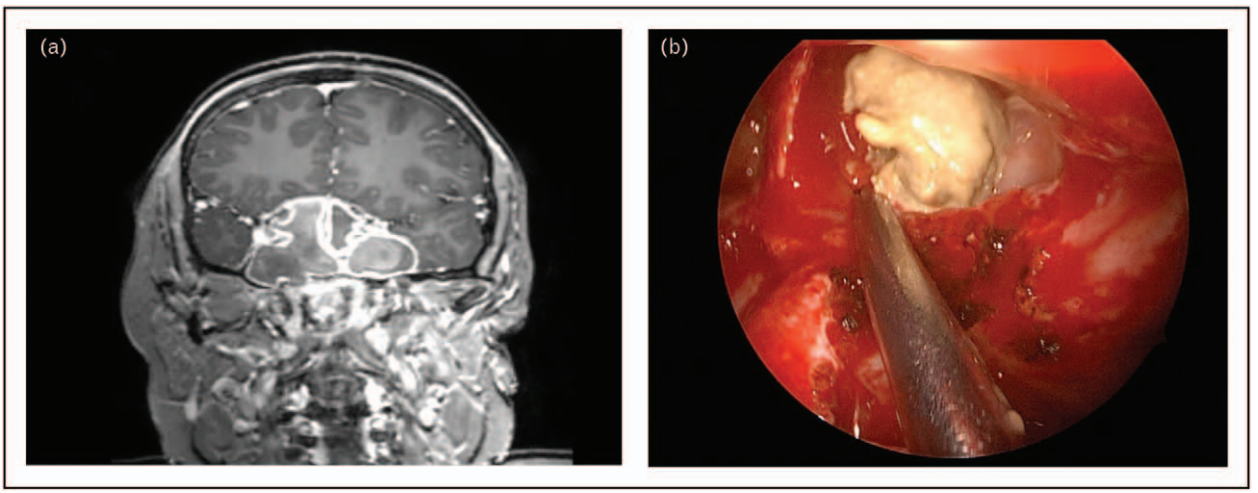

FIGURE 3. 16-year-old female with severe allergic fungal sinusitis seen on MRI (a) found to have eosinophilic mucin and fungal debris in the left sphenoid sinus during endoscopic surgery (b).

sensitive at detecting mucosal inflammation, so much so that there are concerns for overdiagnosis based on CT findings alone [25,26]. The Lund-Mackay system was developed to quantify levels of mucosal thickening on CT to determine optimal thresholds for diagnosing CRS. Within the pediatric population, scores less than 2 had excellent negative predictive value whereas scores greater than 5 had excellent positive predictive value for CRS (sensitivity 86%, specificity 85%) [27]. CT scans also provide high-resolution images of anatomical variation and can be used with navigation during surgical procedures.

The concern with paranasal CT imaging in pediatrics is the additive exposure to head radiation. A small absolute increase but significant correlation was found between dose of radiation to the head and risks of developing brain and hematologic cancers. A three times risk of brain cancer was seen after a cumulative 60 mGy (2–3 head CTs) to brain tissue and a three times risk of hematologic cancer was seen after 50 mGy (10–15 head CTs) to red marrow [28]. Newer pediatric protocols may reduce the amount of radiation whereas maintaining adequate imaging fidelity. Current guidelines maintain the recommendation of CT for diagnosing pediatric CRS but with keeping these risks in mind. Magnetic resonance imaging (MRI) is recommended for complicated CRS to evaluate for intracranial or orbital involvement [6]. Plain radiographs are not recommended by the AAO-HNS nor EPOS.

MEDICAL TREATMENT

Oral antibiotics

Evidence supporting the use of antibiotics is limited and few well-designed studies are found in the literature despite its widespread use in treating pediatric CRS. In a double blind, randomized study of 77 children with purulent rhinosinusitis for three months, Otten *et al.* compared treatment with one week of cefaclor versus placebo after sinus aspiration and washout. At six weeks follow-up, they found no significant difference in resolution of CRS clinically or radiographically (64.8% in the cefaclor group versus 52.5% in the placebo group; $P = 0.28$) [29]. However, this study was limited by the short duration of antibiotic treatment and pretreatment with sinus aspiration and washout in both groups, which may have obscured any incremental benefit conferred by oral antibiotic therapy.

Due to the limited evidence in pediatric CRS, the choice and duration of empiric antibiotics are derived from treatment of pediatric acute rhinosinusitis. The EPOS guidelines recommend amoxicillin for initial treatment [6]. However, with rising concerns for beta-lactamase producing bacteria, the Infectious Disease Society of America (IDSA) guidelines recommend trialing with amoxicillin-clavulanate (in children: 45 mg/kg per day divided every 12 h). In cases of penicillin allergy, dual therapy with a third-generation cephalosporin and clindamycin (in children: 20–40 mg/kg per day divided every 6–8 h) or levofloxacin can be used [30]. If fluoroquinolones are used, the risk of arthropathy should be discussed with the patient and family. The optimal duration of antibiotic treatment is unknown but both the EPOS and AAO-HNS advocate for longer courses of therapy given likely equivalence to adult CRS. Although the EPOS have not recommended a specific timeframe, the AAO-HNS have reached a consensus that 20 days of treatment is likely superior to 10 days [2,6].

Intravenous antibiotics

Investigations into the utility of intravenous (IV) antibiotics in medically refractory pediatric CRS have been meager. In one retrospective study of 70 children who failed oral antibiotics, 89% of participants demonstrated complete resolution following maxillary sinus washout with or without adenoidectomy and 1–4 weeks of culture-directed IV antibiotics [31]. However, 14% of this cohort developed complications related to prolonged IV access. A similar retrospective study analyzed 22 children who underwent maxillary sinus washout with adenoidectomy and culture-directed IV antibiotics until resolution of symptoms (mean 5 weeks duration) which was achieved in all subjects [32]. There was durable resolution of symptoms at 12 months in 77% of this cohort. Although there is clearly a great clinical benefit to these therapies, it is difficult to isolate the contribution of IV antibiotics from the surgical intervention given the lack of a placebo or oral antibiotic control group. Due to these limitations, the EPOS guidelines do not recommend the use of IV antibiotics in routine pediatric CRS [6].

Steroids

Only one randomized controlled clinical trial has been performed evaluating intranasal steroids in 127 children with CRS with nasal polyposis. The intent of this study was to provide evidence for the safety of intranasal mometasone but the authors also reported improvement in congestion not reaching statistical significance [33]. However, the authors do acknowledge their study was not adequately powered to evaluate outcomes. Given the ample evidence of safety and efficacy of intranasal steroids in treating pediatric AR and the efficacy in treating adult CRS, intranasal steroids are recommended by AAO-HNS and EPOS as first line treatment for pediatric CRS [34–38].

Oral steroids as an adjunct to antibiotic therapy for pediatric CRS has been studied in one trial involving 48 children. Subjects were given a 1 mg/kg/d (max 40 mg/d) methylprednisolone ten-day regimen followed by a five-day taper or placebo with a concurrent 30-day amoxicillin/clavulanate course. There was a significantly greater improvement in CT scan score, cough, nasal obstruction, postnasal drip and total symptom score in the methylprednisolone group. The only reported adverse event was increased appetite and weight gain, which was more common in the steroid group [39]. Concurrent steroid and antibiotic therapy may be superior to antibiotics alone, but this should be weighed against the risks of systemic steroids when discussing combined treatment with patients and family.

Nasal saline irrigations

The most recent AAO-HNS consensus statement on pediatric CRS recommends daily nasal saline irrigation (NSI) as adjunctive medical therapy [2]. However, a recent systematic review found that there were no high-quality data demonstrating the efficacy of NSI in pediatric CRS due to retrospective study design or lack of appropriate control groups in these pediatric studies [40]. This consensus statement recommendation is likely based on a pair of retrospective studies showing 66% resolution of symptoms but with no comparator group and significantly decreased rate of surgical intervention among patients with good versus poor compliance [41,42]. A broader Cochrane review in which three of eight studies included pediatric subjects found NSI to be helpful in the treatment of CRS [43]. Overall, NSI compliance in children is good with 86% of subjects reporting tolerating treatment in one study [44]. In perhaps the most rigorous study on NSI for pediatric CRS, Wei *et al.* compared daily NSI versus irrigation with saline/gentamicin and found significant improvement in quality of life (QOL) scores and CT scores, but no significant difference between them [45].

Biologics

Over this past decade, significant advancements in the treatment of type 2 inflammatory disease have been made. Novel biologics targeting key cytokines IL-4, IL-5, and IL-13 as well as IgE have emerged as promising therapies for type 2 inflammatory diseases such as AR, asthma, or CRS with nasal polyposis (CRSwNP). These T_H2 (T helper type-2) mediated diseases are driven by CD4 + Th2 and type 2 innate lymphoid cells (ILC2) which are the primary producers of IL-4 and IL-13 [46▪▪]. Dupilumab is a monoclonal antibody that targets the IL-4 and IL-13 receptors and prevents B cell proliferation, IgE class switching, and epithelial cell changes seen in type 2 inflammatory diseases. Dupilumab has been Federal Drug Administration (FDA) approved for add-on treatment of inadequately controlled CRSwNP in adults and moderate to severe atopic dermatitis or asthma in adults and adolescents age 12 or older. Omalizumab is a monoclonal antibody that targets IgE and has been approved for treatment of severe persistent asthma in patients age 6 or older. In a recently published pair of randomized controlled trials, omalizumab was shown to produce significant improvements in polyp size and nasal symptoms up to 24 weeks after initiation of therapy with concurrent improvements in asthma QOL scores [47]. There was no significant difference in adverse events between either biologic and placebo,

with the most common being nasopharyngitis, epistaxis, asthma exacerbation and headache.

Robust head-to-head comparison studies of sinus surgery versus biologics have not been undertaken. To date, there is one publication evaluating omalizumab versus surgery in a small cohort of asthmatic patients with concurrent grade 3 nasal polyps that found equivalent improvement in SNOT-22 scores at week 16 [48]. Although patients may prefer to avoid surgery, the effectiveness of biologics in preventing or reducing the need for eventual surgery is not yet established. However, given that surgery cannot prevent recurrence of polyps, there is a clear role for biologics in the treatment of severe, recurrent CRSwNP. At this time, dupilumab is the only biologic FDA approved for the treatment of CRSwNP in adults, although it is approved for use in adolescents age 12 or older for other indications and is occasionally prescribed off-label for this age range to treat pediatric CRSwNP.

The following five criteria for administering biologics as adjunct therapy in CRSwNP has been proposed by EUFOREA (European Forum for Research and Education in Allergy and Airway Disease): Evidence of type 2 inflammation, need for two or more courses of systemic corticosteroids in the past year, significant impaired QOL, significant loss of smell, and diagnosis of asthma [49]. The EUFOREA recommend trialing biologics in postsurgical patients meeting three criteria, whereas utilizing it for surgery-naïve patients meeting four criteria. An evaluation of treatment response should be made at 16 weeks and one year including reductions in nasal polyp size, need for systemic corticosteroids, impact of comorbidities, improvements in sense of smell and QOL.

Surgical

Adenoidectomy with and without sinus irrigation

It has been established that the often enlarged adenoid tissues in children may act as a reservoir for bacterial biofilms responsible for recurrent rhinosinusitis and other URTIs [50]. In comparing adenoid specimens of children with CRS versus sleep disordered breathing (SDB), Zuliani showed that 95% of the adenoid surface in specimens collected from CRS patients had bacterial biofilms present whereas only 2% of the surface was covered in those with SDB [51]. These biofilms tend to be polymicrobial and antibiotic resistant and can contribute to negative bacterial cultures. Therefore, adenoidectomy has been recommended as a first-line surgical treatment for medically refractory pediatric CRS and has been effective in reducing the symptoms of CRS in a majority of those treated [52]. Typically maxillary sinus irrigation is also performed concurrently. However, there is variation (47–61%) in reported success rates after adenoidectomy alone, which may be related to differences in surgical approach and outcome measures collected [53]. Due to the relative efficacy and low risks involved, the EPOS and AAO-HNS consensus statement recommend adenoidectomy for first-line surgical treatment of pediatric CRS.

Balloon catheter dilation

Balloon catheter dilation (BCD) was approved by the US Food and Drug Administration for use in children in 2006. Traditionally patients that failed adenoidectomy underwent functional endoscopic sinus surgery (FESS), but the development of minimally invasive techniques has made BCD an appealing option. BCD treats maxillary, sphenoid, or frontal sinus disease by dilating the ostiomeatal complex or opening the sphenoethmoid or frontal recess to improve drainage and access for irrigation. Because BCD is associated with less mucosal disruption, there may be less synechiae formation or ostial stenosis with BCD and therefore less frequent postoperative sinus debridements would be required (Table 1).

General anesthesia is required in most young pediatric patients, however, teenagers may be tolerant of BCD under local anesthesia. Although preparing the device, the nose is decongested with pledgets and local anesthesia (either injection or topical gel). In most BCD systems, a guidewire is placed into the targeted sinus endoscopically and confirmed with direct visualization, transillumination or by image guidance. The balloon is then advanced over the guidewire and inflated. Most systems also can perform sinus irrigation over the catheter channel after dilation. Typically, nasal packing is not required after BCD.

The safety and feasibility of BCD in children were established in 2009 by a study involving 30 children who had failed medical management (Table 2). The procedure was successful in 91% of sinuses, with four failures occurring in hypoplastic maxillary sinuses and one in a hypoplastic frontal sinus [54]. No complications were reported [55]. In a subsequent study, the efficacy of BCD with or without adjunct procedures was evaluated, which showed that 81% of patients ($n = 26$) undergoing BCD alone, BCD with anterior ethmoidectomy or BCD with revision adenoidectomy had reduction of 0.5 on postoperative SN-5 score [56]. Additionally, a

Table 1. Advantages and disadvantages of balloon catheter dilation in pediatric CRS

Advantage	Disadvantage
Less dissection of anatomy required and mucosal disruption - less synechiae formation and ostial stenosis - decreased postoperative debridements	Increased total cost of procedure due to disposable instruments
Facilitates irrigation of the sinuses	Contraindicated in patients with osteoneogenesis, nasal polyposis, or extensive mucosal disease
Surgical tool for dissection of difficult to reach frontal recess cells	Hybrid technique necessary in patients with complex pneumatization patterns to avoid worsening obstruction
Possible decreased blood loss	Surgeon must be able to perform traditional surgery if balloon catheter dilation fails
Possible use in critically ill patients unable to tolerate general anesthesia	Technical difficulty in accessing hypoplastic sinuses
For teenagers able to cooperate, possible use in office setting with minimal anesthetic requirements	Unclear efficacy in patients with immunodeficiency or other co-morbidities

CRS, chronic rhinosinusitis

recent single-arm trial including 50 children (157 sinuses dilated) reported durable improvement in minimal clinically important difference (MCID) of at least 1.0 on the SN-5 at 6 months [57]. 40% of these patients underwent BCD alone, whereas among those undergoing adjuvant procedures the most common were adenoidectomy (42%), inferior turbinate reduction (26%) and ethmoidectomy (12%). Nevertheless, multivariate analysis controlling for adjuvant procedures suggested that BCD independently contributes to efficacy. Due to the lack of control group and randomization in this study design, causality could not be proven [58]. Additionally, subjective scores rather than imaging or endoscopic findings were used to measure outcomes.

In contrast, a more recent randomized blinded trial including 25 children showed no QOL benefit of BCD with irrigation and adenoidectomy versus adenoidectomy and maxillary sinus irrigation [59]. Both groups received sinus aspiration and irrigation with approximately 15–25 mL saline and demonstrated improvement in overall symptom scores, however, no additional benefit was seen in the group that also underwent BCD.

Functional endoscopic sinus surgery

Patients that have continued CRS symptoms after adenoidectomy are candidates for FESS. A meta-analysis of FESS results showed an 88% success rate and 0.6% incidence of complications, proving its efficacy and safety in the pediatric population [60]. In a nonrandomized study comparing adenoidectomy with FESS, Ramadan showed greater improvement in symptoms in the FESS group (77%) compared to the adenoidectomy group (47%) [61]. When stratifying by age, children over the age of 6 had a significantly greater success rate (89% versus 73%) than those younger than 6 years old [62]. Concerns about the impact on facial growth have been resolved by a long-term study [63]. A recent study found that presence of nasal allergy, younger age and higher Lund-Mackay score was associated with requiring revision surgery [64▪].

There are no well-designed studies that answer the question of what extent of FESS is indicated in pediatric CRS. Many suggest a conservative approach to FESS in children with uncomplicated CRS that should be limited to removal of any obvious obstructions, maxillary antrostomy and anterior ethmoidectomy. Typically, FESS is reserved for children who have failed medical management and adenoidectomy. However, in those with CF, nasal polyposis, antrochoanal polyps or allergic fungal sinusitis, FESS is used first line to reduce disease burden although the evidence to support this is not derived from randomized prospective studies.

Based on the available evidence, the most supported surgical treatment algorithm for the uncomplicated pediatric CRS patient who has failed medical management should begin with an adenoidectomy with maxillary sinus irrigation, followed by conservative FESS if symptoms should recur. For patients with CF, polyposis, antrochoanal polyps or allergic fungal sinusitis, first line endoscopic sinus surgery is recommended to decrease disease burden. Since the introduction of BCD, it has been shown to be a safe technique in children although its efficacy compared to traditional sinus surgery cannot be determined based on current studies. Therefore, BCD can be offered as an adjunct therapy to patients undergoing adenoidectomy up until requiring traditional FESS. Future randomized controlled prospective studies are needed to further establish the

Table 2. Literature review of efficacy of surgical interventions for pediatric chronic rhinosinusitis

Year	Author	Type	Comparison groups	N	Age range (mean)	Outcome measures	Length of follow up	Conclusions	Limitations
1999	Ramadan	Prospective, nonrandomized	Endoscopic sinus surgery vs adenoidectomy	69	2–14 (7.2)	Caregiver reported symptomatic improvement	1 year	Endoscopic sinus surgery is better than adenoidectomy in treating chronic refractory pediatric CRS	
2008	Brietzke	Meta-analysis	3 Adenoidectomy versus continued medical management, 7 adenoidectomy case series	10–121	4.4–6.9 (5.8)	Caregiver reported symptomatic improvement	1–9 months	Adenoidectomy reduces caregiver reported symptoms of chronic rhinosinusitis	
2010	Ramadan	Prospective, nonrandomized	BCD ± adenoidectomy versus adenoidectomy alone	49	2–11 (7.7)	SN-5	1 year	BCD is safe, and more effective compared to adenoidectomy alone.	Unable to dilate hypoplastic sinuses
2012	Ramadan	Prospective, single-arm	BCD after adenoidectomy failure	26	4–12 (9.0)	SN-5	1 year	BCD is safe and effective in children for whom previous adenoidectomy has failed prior to ESS	4 also had anterior ethmoidectomy. 3 had a contralateral maxillary antrostomy for a hypoplastic sinus or failed cannulation with the balloon. 2 underwent revision adenoidectomy.
2017	Soler	Prospective, single-arm	BCD with or without adenoidectomy or other adjuvant procedures (±ethmoidectomy, ±inferior turbinate reduction)	50	2–21 (6.6)	SN-5, SNOT 22 (age > 12), RSI, revision rate	0.5 years	BCD effective for pediatric CRS of 2 years or older	Lack of control group
2018	Gerber	Prospective, randomized, blinded	Adenoidectomy with maxillary sinus irrigation via needle puncture; versus Adenoidectomy with maxillary sinus irrigation via BCD	12 BCD 13 control	2–12 years	SN-5	1 year	The addition of BCD to adenoidectomy/maxillary sinus irrigation did not provide additional QOL and sinonasal symptom improvement	

BCD, balloon catheter dilation; CRS, chronic rhinosinusitis; QOL, quality of life

optimal timing of BCD in the current surgical approach to pediatric CRS.

CONCLUSION

The development of CRS in children is multifactorial with the adenoids comprising a larger role compared to adult CRS. Medical therapy remains first line in the treatment of uncomplicated pediatric CRS with surgical intervention reserved for cases not well controlled by medication. New advances in BCD and biologics may serve as useful adjuncts in surgical and medical therapy respectively with additional research needed to better delineate the optimal indications for each in the treatment continuum. Evidence for treatment options in pediatric CRS continues to lag that of adult CRS.

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- ■ of special interest
- ■■ of outstanding interest

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