

Chronic sinusitis among pediatric patients with chronic respiratory complaints

Kim-Lien Nguyen, MD, Mark L. Corbett, MD, Daniel P. Garcia, MD, Steve M. Eberly, MD, Evan N. Massey, MD, Ha T. Le, MD, Loretta T. Shearer, MD, John M. Karibo, MD, and Hobert L. Pence, MD
Louisville, Ky.

We examined the prevalence of chronic sinusitis among children who presented to allergy clinics with chronic (≥ 3 months) respiratory symptoms. Ninety-one patients, ranging from 2 to 17 years of age with 62% male and 72% white, completed the study. Fifty-nine percent of patients had positive skin test results, and 25.3% had chronic asthma. Paranasal sinuses were examined by coronal sinus computed tomographic scan. Sixty-three percent (58 of 91) had chronic sinusitis, 5.5% (5 of 91) had concha bullosa, 1% (1 of 91) had foreign body, and 19% (19 of 91) had deviated nasal septums. Among symptoms of sneezing, nasal congestion, postnasal drip, coughing, wheezing, rhinorrhea, and headache, no single symptom was an acceptable predictor of abnormality on computed tomographic scan examinations. Combining the symptoms of moderate to severe rhinorrhea and cough with minimum sneezing had a specificity of 95% and a sensitivity of 38% in predicting the presence of chronic sinusitis. Allergic rhinitis ($p = 0.27$), mild deviated nasal septum ($p = 0.11$), unobstructive concha bullosa ($p = 0.13$), and passive exposure to cigarette smoke ($p = 0.53$) were not risk factors associated with sinus abnormalities. Age ($r = 0.30$, $p = 0.004$) in pediatric patients with chronic respiratory symptoms was the single risk factor significantly associated with abnormalities on sinus computed tomographic scan. Seventy-three percent of children 2 to 6 years of age, 74% of children 6 to 10 years of age, and 38% of children older than 10 had chronic sinusitis. Chronic sinusitis is common among pediatric patients with chronic respiratory symptoms. Because the clinical symptoms are not acceptably sensitive, imaging studies of the sinus such as a Waters' view roentgenogram should be considered as part of an allergy evaluation, especially in a high-risk group of patients from 2 to 10 years of age. (J ALLERGY CLIN IMMUNOL 1993;92:824-30.)

Key words: Sinus computed tomographic (CT) scans, chronic sinusitis, risk factors, pediatric patients, allergy skin tests

Upper respiratory tract infections (URIs) are the most common disorders encountered in the pediatric age group. Approximately 5% to 10% of URIs are complicated by acute sinusitis.¹ Sinusitis is classified by the duration of clinical symptoms: acute (less than 30 days), subacute (3 weeks

Abbreviation used:

URI: Upper respiratory tract infection

to 2 months), and chronic (more than 2 to 3 months).^{2, 3} The clinical presentation of chronic sinusitis is a manifestation of upper respiratory tract inflammation with postnasal drip, rhinorrhea, cough, increased wheeze, and sore throat.⁴⁻⁷ Chronic sinusitis is frequently recurrent or marked by exacerbated episodes.⁸ In addition, it is suggested that allergic and nonallergic rhinitis are risk factors for the development of chronic sinusitis.^{9, 10} Therefore children with unrecognized chronic sinusitis are frequently referred for an allergy evaluation.^{11, 12} In an allergy clinic where children with chronic or recurrent respiratory

From the Department of Internal Medicine, the Department of Pediatrics, Section of Allergy and Immunology, University of Louisville, School of Medicine, Louisville, Kentucky.

Received for publication Feb. 5, 1993; revised May 7, 1993; accepted for publication May 11, 1993.

Reprint requests: Kim-Lien Nguyen, MD, The University of Louisville, School of Medicine, Kosair's Children's Hospital, Pediatric Allergy Clinic, 231 E. Chestnut, Louisville, KY 40202.

Copyright © 1993 by Mosby-Year Book, Inc.
0091-6749/93 \$1.00 + .10 1/1/48518

symptoms of either excessive viral URI, unrecognized chronic sinusitis, asthma, or allergic or non-allergic rhinitis are referred for an allergy evaluation, how does one recognize, diagnose, and treat chronic sinusitis appropriately when almost all of the above diseases share common and overlapping clinical presentations as a manifestation of respiratory inflammation of different causes?

The purposes of our study were to examine (1) the prevalence of chronic sinusitis in pediatric patients who presented with chronic respiratory symptoms to referral allergy clinics; (2) the symptom complex that may distinguish childhood chronic sinusitis from chronic allergic and nonallergic rhinitis; and (3) the associated risk factors in the pathogenesis of chronic sinusitis in pediatric patients.

METHODS

Patients

All new patients, of either sex and ranging from 2 to 18 years of age, who had upper respiratory tract symptoms for at least 3 months were eligible to enter the study. Patients who had gross facial deformities, known cystic fibrosis, or immunodeficiency were excluded. All patients were seen from July 1991 through February 1992, at a referral private allergy practice and at the allergy clinic of Kosair's Children's Hospital, in the Greater Louisville area, Kentucky. The protocol was approved and monitored by The Human Studies Committee at The University of Louisville, School of Medicine.

All eligible patients had skin tests to common aeroallergens in the area, full coronal computed tomographic (CT) scan of paranasal sinuses, and detailed history and physical examination.

Allergy skin testing

Skin tests were performed by the modified prick method to histamine, saline controls, and 30 common aeroallergens (Hollister-Stiers, Spokane, Wash.) in the area.¹³ The concentration of the 50% glycerine-saline testing extracts used for prick testing was 1:20 wt/vol. Selective intradermal tests at 1:1000 wt/vol were also performed at the discretion of the study physicians.¹⁴⁻¹⁶ Reactions were read at 15 minutes. A negative skin test result had no reaction or had a reaction that was no different from the negative control. A positive reaction was considered to be a wheal greater than 2 mm larger than the negative control with the accompanying flare reaction.

CT scan of the paranasal sinuses

CT scan of the sinuses consisted of coronal views, at 4 mm intervals, with both soft tissue and bony window images. All patients from 2 to 4 years of age and uncooperative older patients were sedated with chloral hydrate according to the protocol of the institution. The

sedation protocol was supervised by the radiologists. All films were read by a single radiologist blinded to the clinical information. Any abnormality had to be noted on both soft tissue and bony window images to prevent false-positive readings as a result of overinterpretation of the "averaging" effect¹⁷ of soft tissue window images. CT scans were interpreted as follows: (1) negative, if there were no abnormalities except the presence of a simple cyst or mucocoele; (2) minimal disease, if there was mucosal thickening occupying less than 20% to 25% of diseased sinus' volume; (3) significant disease, if mucosal thickening, air-fluid level or opacification occupied more than 25% of diseased sinus' volume. Frontal, ethmoid, sphenoid, left and right maxillary sinuses were considered individually in evaluating the absence or presence of disease.

Rhinitis/sinusitis symptom scores

The severity of clinical symptoms of rhinorrhea/sneezing, nasal congestion, sneeze, postnasal drip, headache, cough, and wheeze were scored from 0 (absent), 1 (mild), 2 (moderate), to 3 (severe) according to the following criteria.¹⁸

- Sneeze/itching (0: none; 1: one to four sneezes per day or occasional itching; 2: five to 10 sneezes per day or annoying itching continuous for more than 30 minutes; 3: distress that may interfere with sleep or concentration)
- Nasal congestion (0: none; 1: some hindrance to breathing, not uncomfortable; 2: nostril(s) feel blocked, need to breath through mouth most of the time; annoying; 3: cannot breath through nose at all, may interfere with sleep, altered odor perception or affected quality of voice)
- Rhinorrhea/sneezing (0: none; 1: sneezing or tissues needed one to four times daily; 2: sneezing or tissues needed five to 10 times daily; 3: nose runs freely despite frequent use of handkerchief or tissues)
- Postnasal drip/snorting (0: none; 1: slight awareness or tickling sensation in throat; 2: frequent throat clearing, annoying; 3: causes gagging or frequent cough, uncomfortable)
- Cough (0: none; 1: occasional cough, not uncomfortable, no interference with school or sleep; 2: frequent cough, annoying but not distressing, 2 to 3 days a week; 3: almost every day and night, distressing spells, may interfere with sleep or school)
- Headache (0: none; 1: occasional headache, spontaneously resolved; 2: frequent headache, one to two times per week, easily controlled with aspirin or acetaminophen; 3: almost an everyday occurrence, lasting 2 to 3 hours, interference with daily activities)
- Wheeze (0: none; 1: occasional spell, less than once a week, lasting 2 to 3 minutes, no treatment needed; 2: one to three times a week, need β -agonist intermittently; 3: almost daily, may interfere with daily activity, continuous use of β -agonist and or other medications)

TABLE I. Demographic data of the study population

Subjects (no.)	91
Age (yr)	7.8 ± 0.48
Range	2 to 17
Sex, male:female	1.5:1
Race, white:black	2.9:1
Positive skin test results (%)	59
Chronic asthma (%)	25.3
Duration of symptoms (yr)	3.17 ± .28 (range, 0.16 to 10)

Definition of chronic sinusitis

Chronic sinusitis was defined according to the criteria proposed by Shapiro and Rachelefsky by the presence of two of three major clinical signs (rhinorrhea, postnasal drip, and cough) for 3 months or longer and confirmed by coronal CT scan with mucosal thickening or opacification of the sinus or sinuses.¹⁹

Statistical analysis

Data are reported as means ± SEM, unless otherwise indicated. The data were analyzed by construction of 2 × 2 tables, chi square analysis, Pearson correlation and multiple regression analysis. The calculations were performed with the STAT2 software program (StatSoft, Inc., Tulsa, Okla.) on a personal computer.

RESULTS

Ninety-one new patients, aged 2 to 17 (mean age, 7.8 ± .48 years), who presented to our allergy clinics from July 1991 to February 1992 with chronic respiratory complaints for at least 3 months' duration were entered in the study. A further 15 eligible new patients, who did not have a CT scan of paranasal sinuses because of accidental omission or parental refusal, were excluded. The demographic data of the study population are shown in Table I. Male patients outnumbered female patients at a ratio of 1.5:1. Seventy-two percent were white. The mean duration of symptoms was 3.17 ± 0.28 years (range, 3 months to 10 years). Fifty-nine percent had positive skin test results, and 25.3% had a history of chronic asthma, which was diagnosed by the patient's primary physicians, for at least 1 year and had been receiving antiasthmatic medications such as β-agonists, cromolyn sodium or steroids by mouth, inhalers, or nebulizers.

Traditionally, the diagnosis of chronic sinusitis has been supported or refuted by abnormalities found by sinus roentgenogram. Because sinus

TABLE II. Clinical symptoms scores of chronic sinusitis versus nonchronic sinusitis

Symptoms	Abnormal sinus CT scan	Negative sinus CT scan
	Scores (mean ± SEM)	
Nasal congestion	2.18 ± 0.11	2.16 ± 0.11
Postnasal drip	1.72 ± 0.16	1.40 ± 0.16
Headache	0.77 ± 0.15	0.74 ± 0.15
Wheezing	0.54 ± 0.11	0.86 ± 0.15
Sneezing	1.16 ± 0.14*	1.72 ± 0.16
Rhinorrhea	2.35 ± 0.11*	2.04 ± 0.14
Coughing	1.8 ± 0.14*	1.23 ± 0.12

* $p < 0.05$.

roentgenograms had significant false-positive and false-negative rates,²⁰⁻²³ especially in the pediatric population, we used the more superior imaging technique of CT scan to detect sinus disease in this study. Judging by the criteria proposed by Shapiro and Rachelefsky,¹⁹ of the 91 studied patients, 58 (63%) had chronic sinusitis with appropriate clinical signs and abnormal coronal CT scans, and 33 (36%) had no sinus disease. Among patients who had chronic sinusitis, pansinusitis occurred in 21 cases (36%). Twenty-four cases (41%) had disease detected in multiple sinuses (at least two different groups of sinuses). There were 13 cases (22%) in which disease occurred in a single sinus: 3 cases (5%) had significant sinus abnormalities with greater than 25% mucosal thickening or opacification, and 10 cases (17%) had only minimal (< 20% to 25% mucosal thickening) disease. CT scans also detected deviated nasal septum in 19 patients (21%), foreign body in one patient (1%), and concha bullosa in five patients (5%). Neither deviated nasal septum nor concha bullosa was obstructive to the osteomeatal complex.

Because most children who presented to an allergy clinic frequently had chronic upper and/or lower respiratory complaints,⁴⁻⁶ we examined the association of sneezing, rhinorrhea, nasal congestion, postnasal drip, headache, cough, and wheeze with the abnormalities found by the sinus CT scan. None of the patients in the study had fever. Nasal congestion ($p = 0.80$), postnasal drip ($p = 0.16$), headache ($p = 0.09$), and wheezing ($p = 0.85$) had no statistically significant association with the presence or absence of sinus abnormality. Although there was a statistically significant association of sneezing ($r = -0.28$, $p =$

TABLE III. Associated risk factors: Nasal structural abnormalities, skin tests, cigarette smoke exposure, and age

Risk factors	Abnormal sinus CT scan (no.)	Negative sinus CT scan (no.)	p Value
Deviated nasal septum	7/19	12/19	0.11
Concha bulosae	1/5	4/5	0.13
Foreign body	1	0*	
Exposure to cigarette smoke	25/45	20/45	0.53
Skin test results			
Positive	32/51	19/51	0.27
Negative	27/36	9/36	
Age			0.004
2 to 6 yr	28/38	10/38	
> 6 to 10 yr	20/27	7/27	
> 10 yr	10/26	16/26	

*Subgroup was too small to analyze.

0.006), rhinorrhea ($r = 0.25$, $p = 0.01$), and cough ($r = 0.27$, $p = 0.009$) with sinus CT scan abnormality, the strength of each association was negligible ($r^2 \leq 0.09$) (Table II). When the three symptoms of rhinorrhea, cough, and the absence of sneezing were combined, the association was significantly stronger ($r = 0.49$, $p = 0.0001$, and $r^2 = 0.24$). The specificity of the symptom complex of moderate to severe rhinorrhea and cough in conjunction with absent or mild sneezing as a predictor of significant sinus disease was 95%; however, the sensitivity was unacceptably low at 38%. The sensitivity increased to 57% if we used only the moderate to severe cough and rhinorrhea as clinical predictors of sinus abnormality; however, the specificity decreased to 74.4%.

We then attempted to determine whether there were any immunologic or demographic factors associated with chronic sinusitis in these studied patients. We found no correlation between atopic status and sinus abnormality ($\chi^2 = 1.2$, $p = 0.27$). Ninety-five percent (86 of 91) of patients in the study had allergy skin tests, of which 59% were positive. The prevalence of sinus disease was 63% for atopic patients versus 75% for nonatopic patients (Table III). Of 23 patients who had a history of clinical asthma, eight (34%) had chronic sinusitis.

Among 19 patients with deviated nasal septum, seven (36%) had sinus disease. Only one of five patients (20%) with concha bullosa had an abnormal sinus CT scan. Chronic sinusitis was present in association with a foreign body in one patient. The foreign body was not detectable by sinus roentgenogram (Table III).

Presence of cigarette smoker(s) in the household did not increase the risk of sinus abnormality in our study, even though passive exposure to cigarette smoke has been implicated in the pathogenesis of otitis media and URI in children.²⁴ Fifty five percent of smokers' children versus 47% of nonsmokers' children ($\chi^2 = 0.41$, $p = 0.53$) had sinus abnormalities as determined by CT scan (Table III).

Age was the single most significant risk factor ($r = -0.30$, $p = 0.004$) associated with chronic sinusitis in this group of children. In the group of 2- to 6-year-olds, 28 of 38 patients (73%) had sinus CT scan abnormalities versus 74% (20 of 27) in the group of 6- to 10-year-olds. In contrast, only 10 of 26 children (38%) over 10 years of age had sinus abnormalities (Table III). The data suggest that patients from 2 to 10 years old who have chronic respiratory symptoms are at higher risk of having chronic sinusitis.

DISCUSSION

Although sinus roentgenogram is the most common imaging method used to evaluate sinus disease, it has long been known to have many pitfalls, especially in the pediatric population.²⁵⁻²⁷ In a study of 70 children with chronic sinusitis, Lusk et al.²⁸ had reported that sinus roentgenograms both overestimated and underestimated the presence of sinus disease as compared with the findings on CT scans. Forty-five percent of normal sinus roentgenograms were found to be abnormal by sinus CT scans, and 34% of abnormal sinus roentgenograms were actually normal. The most definitive methods used to evaluate sinus disease are

coronal sinus CT scans and nasal endoscopy.²⁹ A CT scan provides excellent and superior images of all sinuses including those that are inaccessible to endoscopy.^{30, 31} Because office nasal endoscopy is not tolerated by the majority of children, the CT scan is currently the most reliable method for the examination of the paranasal sinuses.³¹ However, sinus CT scan is not without controversy. Several studies have examined the frequency of incidental sinus abnormalities as determined by CT scan in children.^{32, 33} Diamant et al.³² examined the incidental rate in pediatric patients (neonates to 17-year-olds) using low-resolution (at 10 mm scan thickness) CT scan of the brain to examine the paranasal sinuses. This study failed to correlate the signs or symptoms of recent or recurrent respiratory infection. The authors reported that the high abnormality rate was clustered in the group of 1- to 2-year-olds. Glasier et al.³³ reported a rate of 18% of incidental sinus abnormality on cranial CT scans among pediatric patients (>1 year old) who had no signs or symptoms of URIs. However, this study had some flaws: (1) low-resolution CT scan of the brain was used (at 5 and 10 mm slice thickness), and (2) images were routinely evaluated only at soft tissue window. Low-resolution and soft window images alone frequently lead to false-positive readings.¹⁷ A CT scan of the brain, designed to give an optimal image of both frontal and posterior lobes, certainly was not a complete or ideal examination of the paranasal sinuses. Furthermore, it failed to classify the degree of abnormality of the radiographic findings.

In our study we used high-resolution coronal sinus CT scans (at 4 mm thickness in all patients), and both soft tissue and bone window images were evaluated to prevent false-positive and false-negative readings.¹⁷ We also classified the degree of abnormality of the roentgenographic findings. In addition, our study population's age ranged from 2 to 17 years. Although the CT scan has been widely used, there are no established criteria to classify the degree of abnormality of roentgenographic findings.^{32, 33} In our study instead of measuring mucosal thickening in millimeters, we estimated the degree of abnormality by percent of the total volume of the diseased sinus as first suggested by Van der Veken et al.³⁴ and by Shapiro and Rachelefsky.¹⁹ It gave us a uniform scale with which to evaluate the frontal, ethmoidal, sphenoidal, and maxillary sinuses of varying size because we were dealing with patients from 2 to 17 years of age. Our data confirmed the

high prevalence (63%) of sinus disease found by CT scans in children with chronic respiratory complaints. The result is in concordance with the report from Van der Veken et al.³⁴ of 64% prevalence of chronic sinusitis by CT scan in 196 pediatric patients with chronic rhinorrhea, cough, and nasal congestion. Interestingly, our results are also in agreement with the prevalence reported by Rachelefsky et al.¹⁰ for an atopic population with sinus roentgenograms that show less than 2 mm of mucosal thickening.

Multiple symptoms of chronic sinusitis have been reported with rhinorrhea, nasal congestion, postnasal drip, cough, occasional headache, sore throat, and increased wheezing.⁴⁻¹⁰ However, rhinorrhea, nasal congestion, and postnasal drip are common in allergic and nonallergic rhinitis; cough and wheeze can be a manifestation of asthma; and recurrent sore throat and postnasal drip may occur in recurrent viral URIs. In fact, 94% of the studied patients had at least two of three major clinical symptoms of chronic sinusitis, with variable degrees of severity. This finding is expected because primary physicians and parents of children who have recurrent and/or chronic respiratory symptoms frequently seek a consultation with an allergist. Our data suggest that there is no single symptom complex that is a reliable predictor of chronic sinusitis in this group of pediatric patients. Combining the symptom complex of moderate to severe rhinorrhea and cough with minimal or no sneezing provides a good specificity of 95% but an unacceptable sensitivity of 38% for chronic sinusitis among pediatric patients with chronic respiratory complaints. Other diagnostic aids such as the color of nasal discharge and nasal smears probably at best have supportive value only. Although Shapiro and Rachelefsky¹⁹ consider nasal smears with "many" neutrophils to be confirmatory information, Zimmerman et al.³⁵ reported that nasal smears had no value in their study of chronic sinusitis among patients with asthma.

Although allergic disease has been assumed to be an important risk factor in the pathogenesis of chronic sinusitis, there are no data to confirm this association.^{10, 11} In the 1970s, Rachelefsky et al.¹⁰ first suggested the association with the report of high prevalence of abnormal sinus roentgenograms in a population of allergic children. Recently, Furukawa et al.³⁶ confirmed Rachelefsky's report; however, both studies consisted almost exclusively (100% to 92%) of allergic patients. The authors suggested that further study should

be performed with larger numbers of nonallergic patients.³⁶ In our study both allergic (58.8%) and nonallergic (41.2%) children were almost equally represented. Abnormal sinus CT scans occurred in 63% and 75% of allergic and nonallergic children, respectively. Our data showed that allergic and nonallergic pediatric patients had a similar risk of having chronic sinusitis. Rachelefsky³⁷ also recently reported that only 40% of children with chronic sinusitis have positive allergy skin test results.³⁷ Van der Veken et al.³⁴ found no difference in the incidence of sinus disease between nonatopic and atopic patients. Orobello et al.³⁸ reported no observable correlation between presence of positive skin test results and positive sinus culture.

Among patients who had a clinical history of chronic asthma in our study, 34.7% had chronic sinusitis. In this respect, our result is very similar to the prevalence of 31.2% reported by Zimmerman et al.³⁵ who used a criterion of mucosal thickening of 6 mm or more on sinus roentgenogram.

Although concha bullosa and deviated nasal septums were detected by CT scans, the osteomeatal complex was not obstructed by these variants in any case. Therefore our data suggest that chronic sinusitis in children is rarely associated with gross or obvious anatomic abnormality. Subtle anatomic abnormality can only be evaluated with endoscopy or during sinus surgery by reliable experts such as ear, nose, and throat specialists. There was also no association between exposure to cigarette smoke and abnormal sinus CT scan. Because the association of parental smoking and childhood respiratory tract infection is most evident during the first 2 years of life,²⁷ the lack of association in our study can be in part due to the selection of patients older than 2 years.

Historically, it had been a common belief that children did not have chronic sinusitis until the age of 5; however, Tinkelman and Silk³⁹ demonstrated that young age was the only variable that correlated with positive bacterial cultures of the sinus aspirate in children with chronic sinusitis. Rachelefsky, in an editorial, confirmed that chronic sinusitis may occur in all age groups.³⁷ In our study age was a significant risk factor for abnormal sinus CT scan. The younger the patient who had chronic upper respiratory symptoms, the greater the risk of having chronic sinusitis. Our data is in accordance with the report by Van der Veken et al.³⁴ of a significantly lower mean age of

patients with chronic sinusitis than patients with normal sinuses among 196 patients with chronic upper respiratory symptoms. We speculate that viral URI, subtle anatomic abnormalities or variants, and possibly an immature local immune system such as abnormal mucus secretion may play a more significant role in the development of chronic sinusitis in children than previously suspected. Further studies are needed to clarify these issues.

In summary, chronic sinusitis is very common among pediatric patients with chronic respiratory complaints who seek a consultation with an allergist. Because almost all of the diseases evaluated by allergists are a manifestation of inflammation of the respiratory tract with similar and overlapping clinical symptoms, a high index of suspicion and perhaps screening sinus imaging study such as a Waters' roentgenogram, especially in patients from 2 to 10 years of age, is a necessity. Although sinus roentgenogram has many disadvantages, for practicing allergists it has the advantages of being fast and easy to obtain, as well as inexpensive. With the stricter criteria (opacification, air-fluid level, or mucosal thickening filling at least 50% of antrum) for confirmation of maxillary disease by Waters roentgenogram,¹⁹ the false-positive rate is expected to decrease; however, the high false-negative rate will remain.

We thank O. L. C. J. for his excellent collaboration, kindness, and generosity. We also thank Dr. Ruth E. Redel for her assistance in improving the English usage and Mr. David A. Holt, MSLS, for his technical assistance.

REFERENCES

1. Wald ER, Guerra N, Byers C. Upper respiratory tract infection in young children: duration of and frequency of complications. *Pediatrics* 1991;87:129-33.
2. Kern EB. Sinusitis. *J ALLERGY CLIN IMMUNOL* 1984;74(1):25-31.
3. Bluestone CB. The diagnosis and management of sinusitis in children: proceedings of a closed conference. *Pediatr Infect Dis* 1985;6(suppl):S49-81.
4. Slavin RG. Sinusitis. *J ALLERGY CLIN IMMUNOL* 1984;73:712-16.
5. Wald ER. Sinusitis in children. *Pediatr Infect Dis* 1988;7:S150-53.
6. Ott NL, O'Connell EJ, Hoffman AD, Sachs I, Beatty CW. Childhood sinusitis. *Mayo Clin Proc* 1991;66:1238-7.
7. Patterson R. Allergic diseases: diagnosis and management. Philadelphia: J.B. Lippincott Co., 1985:207-29.
8. Shapiro GG. Sinusitis in children. *J ALLERGY CLIN IMMUNOL* 1988;81:1025-7.
9. Rachelefsky GS, Katz RM, Siegel SC. Chronic sinusitis in the allergic child. *Pediatr Allergic Dis* 1988;35:1091-1101.
10. Rachelefsky GS, Goldberg M, Katz RM, et al. Sinus

- disease in children with respiratory allergy. *J ALLERGY CLIN IMMUNOL* 1978;61:310-4.
11. Shapiro GG. Role of allergy in sinusitis. *Pediatr Infect Dis* 1985;4:S55-S58.
 12. Richards W, Roth RM, Church JA. Underdiagnosis and undertreatment of chronic sinusitis in children. *Clin Pediatr* 1991;30:88-92.
 13. Pepys J. Skin testing. *Br J Hosp Med* 1975;14:412-6.
 14. Malling HJ. Diagnosis and immunotherapy of mould allergy. II. Reproducibility and relationship between skin sensitivity estimated by end point titration and histamine equivalent reaction using skin prick test and intradermal test. *Allergy* 1985;40:354-62.
 15. Maganias NH. The combion test. A new method of allergy testing combining the advantages of prick, scratch and intradermal tests. *Immunol Allergy Pract* 1984;6:393.
 16. Patterson R. Allergic diseases: diagnosis and management. 3rd ed. Philadelphia: J.B. Lippincott Co., 1985:102-22.
 17. Zinreich SJ, Kennedy DW, Rosenbaum AE, Gayler RW, Kumar AJ, Stammberger H. Paranasal sinuses: CT imaging requirements for endoscopic surgery. *Radiology* 1987;163:769-75.
 18. Meltzer EO. Evaluating rhinitis: clinical, rhinomanometric, and cytologic assessments. *J ALLERGY CLIN IMMUNOL* 1988;82:900-8 (Symposium).
 19. Shapiro GG, Rachelefsky GS. Introduction and definition of sinusitis. *J ALLERGY CLIN IMMUNOL* 1992;90:417-8.
 20. McAlister WII, Lusk R, Muntz IIR. Comparison of plain radiographs and coronal CT-scans in infants and children with recurrent sinusitis. *AJR Am J Roentgenol* 1989;153:1259-64.
 21. Swischuk LE, Hayden CK Jr, Dillard RA. Sinusitis in children. *Radiographics* 1982;2:241-52.
 22. Nass RL, Holliday RA, Reedle DL. Diagnosis of surgical sinusitis using nasal endoscopy and computerized tomography. *Laryngoscope* 1989;99:1158-60.
 23. Lew D, Southwick F, Montgomery W, Weber A, Baker A. Sphenoid sinusitis. *N Engl J Med* 1983;309:1149-54.
 24. Richardson MA. Upper airway complications of cigarette smoking. *J ALLERGY CLIN IMMUNOL* 1988;5:1032-5.
 25. Towbin R, Dunbar JS. The paranasal sinuses in childhood. *Radiographics* 1982;2:253-79.
 26. Richardson M, Shapiro G. Ethmoid-sphenoid complex involvement in children with chronic sinusitis [Abstract]. *J ALLERGY CLIN IMMUNOL* 1990;85:286.
 27. Levine H. The sphenoid sinus, the neglected sinus. *Arch Otolaryngol* 1978;104:585-7.
 28. Lusk RP, Rande HL, Muntz HR. The diagnosis and treatment of recurrent and chronic sinusitis in children. *Pediatr Clin North Am* 1989;36:1411-21.
 29. Castellanos J, Axelrod D. Flexible fiberoptic rhinoscopy in the diagnosis of sinusitis. *J ALLERGY CLIN IMMUNOL* 1989;83:91-4.
 30. Carter BL, Runge VS. Imaging modalities for the study of the paranasal sinuses and nasopharynx. *Otolaryngol Clin North Am* 1988;21:395-420.
 31. Zinreich SJ, Kennedy DW, Rosenbaum AE, Gayler BW, Kumar AJ, Stammberger H. Paranasal sinuses: CT imaging requirements for endoscopic surgery. *Radiology* 1987;163:769-75.
 32. Diamant MJ, Senac MO, Gilsanz V, Baker S, Gillespie T, Larson S. Prevalence of incidental paranasal sinus opacification in pediatric patients: a CT study. *J Comput Assist Tomogr* 1987;11:426-31.
 33. Glasier CM, Ascher DP, Williams KD. Incidental paranasal sinus abnormalities on CT of children: clinical correlation. *AJNR Am J Neuroradiol* 1986;7:861-4.
 34. Van der Veken PJV, Clement PAR, Buisseret TH, Desprechins B, Kaufman L, Derde MP. CT-scan study of the incidence of sinus involvement and nasal anatomic variations in 196 children. *Rhinology* 1990;28:177-84.
 35. Zimmerman B, Stringer D, Feanny S, et al. Prevalence of abnormalities found by sinus x-rays in childhood asthma: lack of relation to severity of asthma. *J ALLERGY CLIN IMMUNOL* 1987;80:268-73.
 36. Furukawa CT, Sharpe M, Bierman CW, Pierson WE, Shapiro GG, Altman LC, Virant FS, Williams PV, Minotti DA. Allergic patients have more frequent sinus infection than non-allergic patients [Abstract]. *J ALLERGY CLIN IMMUNOL* 1992;89:332.
 37. Rachelefsky GS. Chronic sinusitis: the disease of all ages. *Am J Dis Child* 1989;143:886-8.
 38. Orobello PW Jr, Park RI, Belcher LJ, et al. Microbiology of chronic sinusitis in children. *Arch Otolaryngol Head Neck Surg* 1991;117:980-3.
 39. Tinkelman DG, Silk HJ. Clinical and bacteriologic features of chronic sinusitis in children. *Am J Dis Child* 1989;143:938-41.