

Microbiology of acute and chronic sinusitis in children

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To determine the bacteriologic cause of acute sinusitis, a sample of sinus secretions must be obtained from one of the paranasal sinuses without contamination by normal respiratory or oral flora that colonize mucosal surfaces. When maxillary sinus aspiration is performed on children who have signs and symptoms of acute sinusitis, bacteria are recovered in high density from 70%. In patients with acute, subacute, or chronic sinusitis who are generally well except for persistent respiratory symptoms, of nasal discharge or cough or both, the usual bacterial isolates are Streptococcus pneumoniae, Haemophilus influenzae, and Moraxella catarrhalis. In contrast, anaerobic organisms and staphylococci should be suspected in patients who have very long-standing symptoms or in those whose symptoms are so severe or complicated that sinus surgery is undertaken. (J ALLERGY CLIN IMMUNOL 1992;90:452-60.)

Key words: Sinusitis, bacteriology, microbiology

Despite the substantial prevalence and clinical importance of sinusitis of childhood, there has been relatively limited study of the microbiology of sinusitis in pediatric patients. In part this limitation is a reflection of the relative inaccessibility of the paranasal sinuses. Unlike the middle ear cavities, the paranasal sinuses cannot be directly inspected by the clinician. Furthermore, aspiration of the paranasal sinuses is not undertaken as easily and therefore not as often as tympanocentesis. This article will review the published studies that have delineated the microbiology of acute and chronic sinusitis in children.

SINUS ASPIRATION

To determine the bacteriology of acute sinusitis, a sample of sinus secretions must be obtained from one of the paranasal sinuses without contamination by normal respiratory or oral flora that colonize mucosal surfaces. The maxillary sinus is the most accessible of the paranasal sinuses. A transnasal approach affords the easiest and safest route of sinus aspiration in pediatric patients. A trocar is passed beneath the inferior nasal turbinate across the lateral nasal wall. However, because the nasal vestibule is so heavily colonized, it

Abbreviation used

cfu/ml: Colony-forming units per milliliter

is essential to attempt to sterilize the area of the nose beneath the inferior turbinate through which the trocar is passed. If this is not done, contaminating nasal flora isolated in the sinus aspirate may be misconstrued as pathogens. Sterilization can be easily accomplished with a topical solution of 4% cocaine. Furthermore, to avoid misinterpretation of culture results, infection is defined as the recovery of a bacterial species in high density, that is, a colony count of at least 10^4 cfu/ml. This quantitative definition increases the probability that organisms recovered from the maxillary sinus aspirate truly represent "in situ" infection and not contamination. In fact most sinus aspirates from infected sinuses are associated with colony counts in excess of 10^4 cfu/ml.

STUDY DESIGN

Using a study design similar to one described by investigators at the University of Virginia,¹ we undertook an investigation of the microbiology of acute sinusitis in pediatric patients in 1979.² Patients were eligible for this study if they were between the ages of 2 and 16 years and had one of two clinical pictures—either onset with "persistent" or "severe" respiratory symptoms. Most subjects had "persistent" symptoms, that is, respiratory symptoms (nasal dis-

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TABLE I. Bacterial species cultured from 79 sinus aspirates in 50 children

Species	Single isolates	Multiple isolates	Total
<i>S. pneumoniae</i>	14	8	22
<i>M. catarrhalis</i>	13	2	15
<i>H. influenzae</i>	10	5	15
<i>Eikenella corrodens</i>	1	0	1
Group A streptococcus	1	0	1
Group C streptococcus	0	1	1
α -Streptococcus	1	1	2
<i>Peptostreptococcus</i>	0	1	1
<i>Moraxella</i>	1	0	1

Modified from Wald ER, et al. J Pediatr 1984;104:297-302.

charge or cough or both) that lasted more than 10 but less than 30 days and had not yet begun to improve. A smaller subset of subjects with acute sinusitis had "severe" respiratory symptoms. Severity was defined as high fever (temperature of at least 103° F) and purulent (thick, colored, and opaque) nasal discharge. For this presentation there was no qualifier on duration of symptoms.

Eligible children with either of these two presentations had sinus radiographs performed. The sinus films were considered abnormal if they showed diffuse opacification, mucosal thickening of greater than 4 mm, or an air-fluid level. If the sinus films were abnormal and informed consent was provided by the parent, then a sinus puncture was performed by means of a transnasal approach.

MICROBIOLOGY OF ACUTE SINUSITIS

When a maxillary sinus aspiration was performed on children who had either persistent or severe symptoms and significantly abnormal sinus radiographs, bacteria in high density were recovered from 70%.³ Table I shows the bacterial species cultured from 79 sinus aspirates obtained from 50 children in their relative order of prevalence. *Streptococcus pneumoniae* was most common, followed closely by *Branhamella catarrhalis* (now known as *Moraxella catarrhalis*), and *Haemophilus influenzae*. Both *M. catarrhalis* and *H. influenzae* may be β -lactamase producing and thereby amoxicillin resistant. The *H. influenzae* found in sinus aspirates, like those found in infected middle ear cavities, are almost always nontypeable organisms, reflecting their frequent colonization of the nasopharynx in contrast to *H. influenzae* type b. Only a single anaerobic bacterial species, a *Peptostreptococcus*, was isolated. No staphylococci were recovered. Mixed infection with heavy growth of two bac-

TABLE II. Bacterial species cultured from 52 sinus aspirates in 40 children

Species	Single isolates	Multiple isolates	Total
<i>S. pneumoniae</i>	9	3	12
<i>H. influenzae</i>	9	2	11
<i>M. catarrhalis</i>	6	2	8
<i>Streptococcus pyogenes</i>	2	0	2
<i>Streptococcus viridans</i>	0	1	1
<i>Moraxella</i>	0	1	1

Modified from Wald ER, et al. J Pediatr 1989;115:28-32.

terial species was occasionally found. In 25% of patients with bilateral maxillary sinusitis, there were discordant bacterial culture results. In some cases one sinus aspirate was positive, whereas the other was negative. In the remaining cases, different bacterial species were recovered from each.

Viral cultures were also performed on the maxillary sinus aspirates. Because many children were evaluated after 10 or more days of symptoms, viruses were recovered infrequently. Adenovirus as the only isolate was grown from the aspirate of one subject; parainfluenza virus in combination with a bacterial isolate was recovered from a second.²

Recently a study with nearly identical design was performed in Mexico City.⁴ Forty-four children ranging in age from 8 months to 12 years with upper respiratory tract symptoms of 1 to 4 weeks' duration were evaluated. All these children had clinical and radiographic evidence of acute sinusitis. Maxillary sinus aspiration was performed as described in the previous study; specimens were cultured quantitatively. Aspirates were obtained from 84 sinuses of 44 children. Bacteria were recovered in colony counts of at least 10⁴ cfu/ml from at least one sinus in 48% of subjects. *S. pneumoniae*, *H. influenzae*, and *Neisseria* species were most frequently isolated. The *Neisseria* species proved to *Neisseria subflava* rather than *M. catarrhalis* when evaluated at the microbiology laboratory of the Children's Hospital of Pittsburgh.

MICROBIOLOGY OF SUBACUTE SINUSITIS

We recently summarized our experience with children who had subacute sinusitis.⁵ These youngsters were evaluated in the context of several different comparative trials of antimicrobial therapy. All children had persistent respiratory symptoms—nasal discharge or cough or both lasting between 30 and 120 days. These children were generally well (with minimal constitutional complaints) except for their respiratory

TABLE III. Bacteria isolated from 37 children with chronic sinusitis

Isolates, aerobic and facultative	No. of isolates	Isolates, anaerobic	No. of isolates
Gram-positive cocci		Anaerobic cocci	
α -Hemolytic streptococci	7	<i>Peptococcus</i> sp.	14
Group A β -hemolytic streptococci	3	<i>Peptostreptococcus</i> sp.	6
Group F β -hemolytic streptococci	1	<i>Streptococcus constellatus</i>	1
<i>S. aureus</i>	7	Microaerophilic streptococci	7
<i>Staphylococcus epidermidis</i>	1	<i>Veillonella parvula</i>	6
Gram-negative bacilli		Gram-positive bacilli	
<i>Escherichia coli</i>	1	<i>Eubacterium</i> sp.	2
<i>H. influenzae</i>	2	<i>P. acnes</i>	8
<i>Haemophilus parainfluenzae</i>	2	<i>Propionibacterium avidum</i>	1
Total	24	<i>Colstridium</i> sp.	3
		Gram-negative bacilli	
		<i>Fusobacterium</i> sp.	6
		<i>F. nucleatum</i>	5
		<i>F. mortiferum</i>	1
		<i>F. necrophorum</i>	1
		<i>Bacteroides</i> sp.	10
		<i>B. melaninogenicus</i>	14
		<i>B. oralis</i>	5
		<i>B. ruminicola</i> ss <i>brevis</i>	5
		<i>B. corrodens</i>	1
		<i>B. biacutus</i>	1
		Total	97

Modified from Brook I. JAMA 1981;246:967-9. Copyright 1981, American Medical Association.

symptoms. Intermittent fever was a complaint in 25% of patients but was rarely documented at the time of presentation. Some of these children had previously received one or more courses of antimicrobial agents. In each case they either failed to respond to the antimicrobial or only improved slightly and experienced a recurrence of symptoms after cessation of antibiotics. Table II shows the bacterial species cultured from 52 sinus aspirates from 40 children. Again, the three predominant organisms were *S. pneumoniae*, *H. influenzae*, and *M. catarrhalis*.

MICROBIOLOGY OF CHRONIC SINUSITIS

Chronic sinusitis has received only limited study in pediatric patients. In 1981, Brook⁶ published a study in which he evaluated 40 pediatric patients with what he described as chronic sinusitis. He defined chronic sinusitis as respiratory symptoms that lasted more than 3 weeks. Some of his subjects had underlying disorders including allergic conditions in 12, local intranasal problems in 5, and cystic fibrosis in 1. In 50% of these patients, specimens for culture were obtained at the time of sinus surgery. Presumably these patients had more protracted and more severe disease than the patients we have discussed thus far. Table III shows

the bacteria isolated from 37 of these 40 patients. Anaerobes were isolated from all of these patients. The most common organisms were anaerobic gram-positive cocci such as staphylococci and streptococci. Another large group was the *Bacteroides* species, especially *B. melaninogenicus*. *Fusobacteria* were also recovered often. Aerobes were isolated in approximately 38%. The most common aerobes were streptococci and staphylococci. *Haemophilus* species were isolated from only four patients.

Quantitative cultures of sinus secretions were not performed in Brook's study. For specimens obtained at surgery this omission probably did not result in the introduction of potentially confounding mucosal contamination because of sterile technique. However, as previously discussed, the lack of quantitation when culturing sinus aspirates may lead to ambiguous results. In Brooks' study, aspirates may have been performed in as many as 50% of patients. Note, for example, that *Propionibacterium acnes* were recovered from eight patients. This bacterial isolate is usual skin or nasal flora, and its recovery in low density almost certainly denotes contamination.

Muntz and Lusk⁷ recently reported the bacteriology of the ethmoid bullae in 105 children between the ages

of 9 months and 17 years with chronic sinusitis. Specimens for culture were obtained from the mucosa of the anterior ethmoid cell in patients undergoing endoscopic ethmoidectomy. All had received at least two courses of an appropriate antimicrobial and were treated until the day before surgery. Although nasal decongestion was achieved with topical cocaine, contamination of the residual ethmoid flora by nasal flora may not be completely avoidable. Furthermore, no quantitation of the bacterial isolates was performed, and antibiotics may surely have eradicated or prevented the growth of other bacterial flora. The most common bacterial species to be recovered were α -hemolytic streptococci and *Staphylococcus aureus* followed by *S. pneumoniae*, *H. influenzae*, and *M. catarrhalis*. Anaerobic organisms were grown from 6% of specimens. This report details the residual bacterial flora in patients who were treated for chronic sinusitis with antimicrobials effective against β -lactamase-producing bacterial species.

The report by Tinkleman and Silk⁸ of data on pediatric patients with chronic sinusitis is included in the interest of completeness, although it has substantial methodologic problems. The study relates bacteriologic findings in 35 of 116 children evaluated for sinusitis at four different hospitals. Standardization of technique is quite unlikely, since culture and sensitivity results were not obtained on 77 patients. Furthermore, all patients received antibiotics at the time of their surgical procedures. The predominant bacterial isolates were *H. influenzae*, *S. pneumoniae*, and *M. catarrhalis*. Group A streptococcus and *S. aureus* were isolated from three patients each.

Another report of patients who had probable chronic sinusitis was that of Shapiro et al.,⁹ who studied 20 patients with cystic fibrosis. In these patients who had chronic cough and radiographically opacified paranasal sinuses, it may be difficult to diagnose sinusitis. Patients were enrolled when they had increased respiratory symptoms, especially nasal discharge and exacerbations of cough. Maxillary sinus aspirates and quantitative cultures were performed as described previously.¹ Table IV shows the bacterial cause of sinusitis in these patients. The most common aerobes identified were *Pseudomonas aeruginosa*, *H. influenzae*, and α -hemolytic streptococci. The anaerobes recovered included anaerobic streptococci, *Bacteroides oralis*, *P. acnes*, and one unidentified gram-negative rod.

MICROBIOLOGY OF SINUSITIS IN ASTHMATIC CHILDREN

Several very small studies of asthmatic children with sinusitis have been conducted. These are prob-

TABLE IV. Bacteria recovered from aspirate material from the maxillary sinuses of 20 patients with cystic fibrosis

Bacteria	No. of sinuses	Only organism isolated
Aerobes	30	---
<i>P. aeruginosa</i>	13	7
<i>H. influenzae</i>	10	5
Nontypeable	9	4
Type A	1	1
α -Hemolytic streptococci (including microaerophilic streptococci)	5	3
<i>Escherichia coli</i>	5	3
<i>S. aureus</i>	1	1
Anaerobes	5	---
<i>Peptostreptococcus</i> sp.	2	---
<i>B. oralis</i>	1	---
<i>P. acnes</i>	1	---
Unidentified gram-negative rod	1	1

Modified from Muntz HR, Lusk RP. Arch Otolaryngol Head Neck Surg 1991;117:179-81. Copyright 1991, American Medical Association.

ably best presented with the chronic sinusitis group, because many patients may experience acute exacerbations of a chronic mucosal process. One such study of eight patients was reported in 1984.¹⁰ Sinus puncture and quantitation were performed as described.² In this small study, half of the children had positive maxillary sinus aspirates. The bacterial species recovered included *M. catarrhalis*, *H. influenzae*, and *S. pneumoniae*. A more recent investigation evaluating 12 children between 3 and 11 years of age with asthma was reported by Goldenhersh et al.¹¹ In this study all subjects had documented respiratory allergy and chronic respiratory symptoms of at least 30 days' duration consistent with chronic sinusitis. All patients had opacification of one or both maxillary sinuses. When maxillary sinus aspiration was performed, *M. catarrhalis* was recovered from six patients, and mixed cultures of streptococci were recovered from three patients. Only one patient had anaerobic streptococci mixed with aerobic streptococci.

CONCLUSION

The studies reviewed herein, except for those reported by Brook⁶ and Shapiro et al.,⁸ have shown remarkably consistent results regarding the microbiology of sinusitis in children. The exceptional bacteriology of sinus infection in patients with cystic fibrosis is not surprising. However, Brook's results can

only be reconciled with the rest by allowing that his patients are different from those studied by other investigators either in the duration or severity of their symptoms.

The microbiology associated with sinusitis can be anticipated according to the patterns of clinical presentation. In patients with acute, subacute, or chronic sinusitis who are generally well except for persistent respiratory symptoms, the usual bacterial isolates are *S. pneumoniae*, *H. influenzae*, and *M. catarrhalis*. In contrast, anaerobic organisms and staphylococci should be suspected in patients with very long-standing symptoms or in those whose symptoms are so severe or complicated that sinus surgery is undertaken. α -Hemolytic streptococci other than pneumococci become important in patients who have protracted symptoms.

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DISCUSSION

Dr. Gwaltney. Would you obtain the aspirate when it first became apparent that the patient was not responding?

Dr. Wald. I think that practically you would probably give someone at least a second course of an antimicrobial. If someone does not respond to amoxicillin-potassium clavulanate the first week, I would think that for some reason either they are not absorbing the drug or they have a resistant organism. I might change therapies at that time. If another 7 days passed without an inkling of a clinical response, that calls for a diagnostic procedure.

Dr. Spector. We have done a study of cefuroxime acetyl versus amoxicillin-potassium clavulanate. The comparison between the two antibiotics was very similar in the cure rate for acute sinusitis, which was about 82% to 85%. We compared 250 mg twice daily of the former for 10 days versus 500 mg three times a day for 10 days, including aspirates of the sinuses, before and after. The big difference between the two drugs was the side effects. Thirteen percent of the amoxicillin-potassium clavulanate-treated patients had diarrhea versus 30% for cefuroxime acetyl treatment. It is pushing me toward giving cefuroxime as first therapy much more than previously. We often did not find anything that we could grow out, and I do not know if it is partly our technique, but in less than 50% of all patients from whom we took cultures could we actually grow any organisms.

Dr. Gwaltney. You certainly do not need to feel bad that you have positive cultures in only 50%, because we have been doing it for 15 years and that is the best we can do.

Dr. Druce. I am not sure how easy it is to make the connection between what you find in the maxillary antra in acute community-acquired sinusitis and what you recover do not recover in chronic sinusitis. This goes along with Gail's point about looking at the ethmoid sinuses, and in fact if we are using sterilizing antral fluid as an endpoint of treatment, that is probably the wrong endpoint to select, if we are talking about treating patients with chronic disease. Maybe we look either at something objective in the ethmoid sinuses or some other parameter, perhaps a clinical one. I also think we need to look more at some of the functions of antibiotics that are not involved with killing bacteria.