A spirates of 15 acutely and 13 chronically infected frontal sinuses were processed for aerobic and anaerobic bacteria. A total of 20 isolates (1.3 per specimen) were recovered from the 15 cases of acute frontal sinusitis, 16 aerobic and facultative isolates (1.1 per specimen) and 4 anaerobic isolates (0.3 per specimen). Aerobic and facultative organisms alone were recovered in 13 specimens (87%), and mixed aerobic and anaerobic bacteria were recovered in 2 (13%). The predominant aerobic and facultative organisms were *Haemophilus influenzae* (6), *Streptococcus pneumoniae* (5), and *Moraxella catarrhalis* (3). A total of 32 isolates were recovered from the 13 cases (2.5 per patient) of chronic frontal sinusitis, 12 aerobic and facultative isolates (0.9 per specimen) and 20 anaerobic isolates (1.5 per specimen). Aerobic and facultative organisms only were recovered in 3 instances (23%), anaerobes only in 7 instances (54%), and mixed aerobic and anaerobic bacteria in 3 instances (23%). The predominant aerobic bacteria were gram-negative bacilli (*H. influenzae*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa*). The predominant anaerobes included *Prevotella* species (8), *Peptostreptococcus* species (6), and *Fusobacterium* species (4). These findings illustrate the microbiologic features of acute and chronic frontal sinusitis.

Frontal sinusitis is a potentially devastating infection with a high frequency of intracranial complication. In contrast to maxillary sinusitis, the microbiologic features of frontal sinusitis are not well established, and only a few reports document the organisms isolated. The role of anaerobic bacteria in this infection was also not well studied, although their recovery was recorded in a few cases. This report describes my experience during a 25-year period of studying the aerobic and anaerobic microbiologic characteristics of frontal sinusitis.

RESULTS

No differences were noted in the microbiologic findings between children and adults, the year of the infection, the administration of previous antimicrobial therapy, or the surgical approach (osteoplastic vs endoscopic).

ACUTE FRONTAL SINUSITIS

A total of 20 isolates were recovered from the 15 cases (1.3 per specimen), 16 aerobic and facultative isolates (1.1 per specimen) and 4 anaerobic isolates (0.3 per specimen). The number of isolates per specimen varied from 1 to 3. Aerobic and facultative organisms alone were recovered in 13 specimens (87%), and mixed aerobic and anaerobic bacteria were recovered in 2 (13%). The predominant aerobic and facultative isolates were *Haemophilus influenzae* (6), *Streptococcus pneumoniae* (5), and *Moraxella catarrhalis* (3) (*Table*). Seven β-lactamase–producing bacteria (BLPB) were recovered from 5 specimens (33%).

CHRONIC FRONTAL SINUSITIS

A total of 32 isolates were recovered from the 13 cases (2.5 per patient), 12 aerobic and facultative isolates (0.9 per specimen) and 20 anaerobic isolates (1.5 per specimen). The number of isolates varied from 2 to 4. Aerobic and facultative organisms only were recovered in 3 in-
PATIENTS AND METHODS

The 28 patients included in the report were studied between June 1975 and June 2001. Excluded are 9 additional patients whose frontal sinusitis showed no bacterial growth. The patients were seen in the following hospitals: University of California Medical Center and County Medical Center in Los Angeles (1974-1977), Children’s Hospital National Medical Center in Washington, DC (1977-1980), and Naval Hospital in Bethesda, Md (1977-1998). Similar microbiologic methods for collection and transportation of specimens were used in these institutions.

Patients’ ages ranged from 11 to 72 years (mean age, 38 years 8 months), and 18 were male. Five patients were children (younger than 18 years). Included in the study were 15 patients with acute and 13 with chronic sinusitis. Antimicrobial therapy was administered to 15 patients (54%) in the month before sample collection. These patients included 10 with acute and 5 with chronic sinusitis.

Only patients who fulfilled the following criteria were included in the study: typical clinical symptoms of sinusitis (headache, fever, nasal drainage); positive radiographic findings; bacterial growth on cultures; biopsy specimens demonstrating acute or chronic inflammation of the sinus mucosal lining; or clinical and radiologic findings compatible with frontal sinusitis followed by clinical and radiologic improvement following surgery and treatment with antibiotics.

Sinusitis was considered acute if the duration of symptoms was less than 1 month and chronic if symptoms persisted for more than 1 month. Frontal surgery was performed by the osteoplastic flap approach in 13 patients and by an intranasal endoscopic approach in 15. Other sinuses were involved at the time of surgery in 6 patients (4 ethmoid and 2 maxillary).

The specimens were obtained during surgery, using strict asepsis to avoid any contamination, and were transported to the laboratory in a syringe sealed with a rubber stopper after evacuation of the air or in an anaerobic transport tube (Port-A-Cul; Baltimore Biological Laboratories, Cockeysville, Md). The time between the collection of materials and inoculation of the specimen was generally less than 60 minutes for syringes and less than 3 hours for the anaerobic transport tube.

Specimens were inoculated onto 5% sheep’s blood, chocolate agar, and MacConkey agar plates for aerobic and facultative organisms. The plates were incubated at 37°C aerobically (MacConkey) or under 5% carbon dioxide (5% sheep’s blood and chocolate agar) and examined at 24 and 48 hours. For anaerobes, the material was plated onto pre-reduced vitamin K1–enriched Brucella blood agar, an anaerobic blood agar plate containing kanamycin sulfate and vancomycin hydrochloride, an anaerobic blood plate containing colistin sulfate and nalidixic acid, and an enriched thioglycolate broth (containing hemin and vitamin K1). The anaerobic plates were incubated in anaerobic jars (GasPak jars; Baltimore Biological Laboratories) and examined at 48 and 96 hours.

Anaerobes were identified by techniques described previously. Aerobic bacteria were identified by conventional methods. β-Lactamase activity was determined by use of the chromogenic cephalosporin analog 87/312 method.

This study demonstrates the microbiologic features of acute and chronic frontal sinusitis. Since the number of patients included in this report was small and was collected during a period of more than 25 years, prospective studies are required. The small number of patients may also account for the lack of correlations between clinical (eg, age and previous antibiotic therapy) and microbiologic findings. Similar to the study by Ruoppi et al, the present study also recovered S pneumoniae, H influenzae, and S aureus from patients with acute frontal sinusitis. These findings are similar to the microbiologic features of acute maxillary sinusitis, where S pneumoniae, H influenzae, and M catharralis predominate, and chronic maxillary sinusitis, where anaerobic bacteria are the main isolates. These were mainly Peptostreptococcus species, Fusobacterium species, and pigmented Prevotella and Porphyromonas species, all members of the oropharyngeal flora.

The frequent involvement of anaerobes in chronic frontal sinusitis may be related to the poor drainage and increased intranasal pressure that develops during inflammation. This can reduce the oxygen tension in the injured sinus by decreasing the mucosal blood flow and depressing the ciliary action. The lowering of the oxygen content and pH of the sinus cavity supports the growth of anaerobic organisms by providing them with an optimal oxidation-reduction potential.

β-Lactam–producing bacteria were isolated in 13 (46%) of 28 patients. The recovery of BLPB is not surprising, since more than half of our patients received antimicrobial agents, including the β-lactams within the past 3 months, which might have selected for these organisms.

Surgical drainage is essential in most cases, and an initial, empiric, broad spectrum antimicrobial coverage is required. However, the unique microbiologic features of acute and chronic frontal sinusitis and the recovery of BLPB in approximately half of the specimens require adjusting an initial empiric therapy to a specific one whenever possible.

The antimicrobial agents most commonly used to treat acute sinusitis include amoxicillin (with and without clavulanate) and amoxicillin-clavulanate.
Vulnus acid (a β-lactamase inhibitor) to amoxicillin increases the risk that it will fail to clear the infection. The addition of clavulanic acid (a β-lactamase inhibitor) to amoxicillin or ampicillin is often used for sinusitis therapy, is safe and inexpensive, and is still, when given in a high dose, the drug of choice for intermediately penicillin-susceptible S pneumoniae. However, the growing resistance of H influenzae and M catarrhalis to amoxicillin increases the risk that it will fail to clear the infection. The addition of clavulanic acid (a β-lactamase inhibitor) to amoxicillin or the use of antimicrobial agents resistant to β-lactamase activity is effective against resistant organisms. The increase in resistance of S pneumoniae to penicillin requires an increase in the amount of amoxicillin administered to patients (up to 90 mg/kg daily in children and 3.0 g/d in adults). This requires the addition of an equal amount of amoxicillin to amoxicillin-clavulanic acid.

The second-generation cephalosporins (cefuroxime axetil, cefprozil, and cefpodoxime proxetil) are active against penicillin-resistant Haemophilus and Moraxella species and intermediate penicillin-resistant S pneumoniae. The newer quinolones (eg, levofloxacin, gatifloxacin, and moxifloxacin hydrochloride) are effective against penicillin-sensitive and penicillin-resistant S pneumoniae and are also active against Haemophilus and Moraxella species.

Antimicrobial agents used for chronic sinusitis therapy should be effective against aerobic and anaerobic BLBP. These include clindamycin, chloramphenicol, the combination of metronidazole and a macrolide or the combination of a penicillin (eg, amoxicillin) and a β-lactamase inhibitor (eg, clavulanic acid), and the newer quinolones (eg, trovafloxacin mesylate and moxifloxacin). Other effective agents are available only in parenteral form (eg, cefoxitin sodium, cefotetan disodium, and cefozaxime sodium). If gram-negative organisms, such as P aeruginosa, are involved, parenteral therapy with an aminoglycoside, a fourth-generation cephalosporin (cefepine hydrochloride or cefazidine sodium), or oral or parenteral treatment with a fluoroquinolone (only in postpubertal patients) is also used. Parenteral therapy with a carbapenem (eg, imipenem) is more expensive, but provides coverage for most potential pathogens, both anaerobes and aerobes.

Prospective studies are warranted to elucidate the role of anaerobic bacteria in acute and chronic sphenoid sinusitis. It is, however, recommended that specimens are obtained for culture from infected sphenoid sinuses for both aerobic and anaerobic bacteria and fungi so that appropriate antimicrobial therapy can be determined.

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